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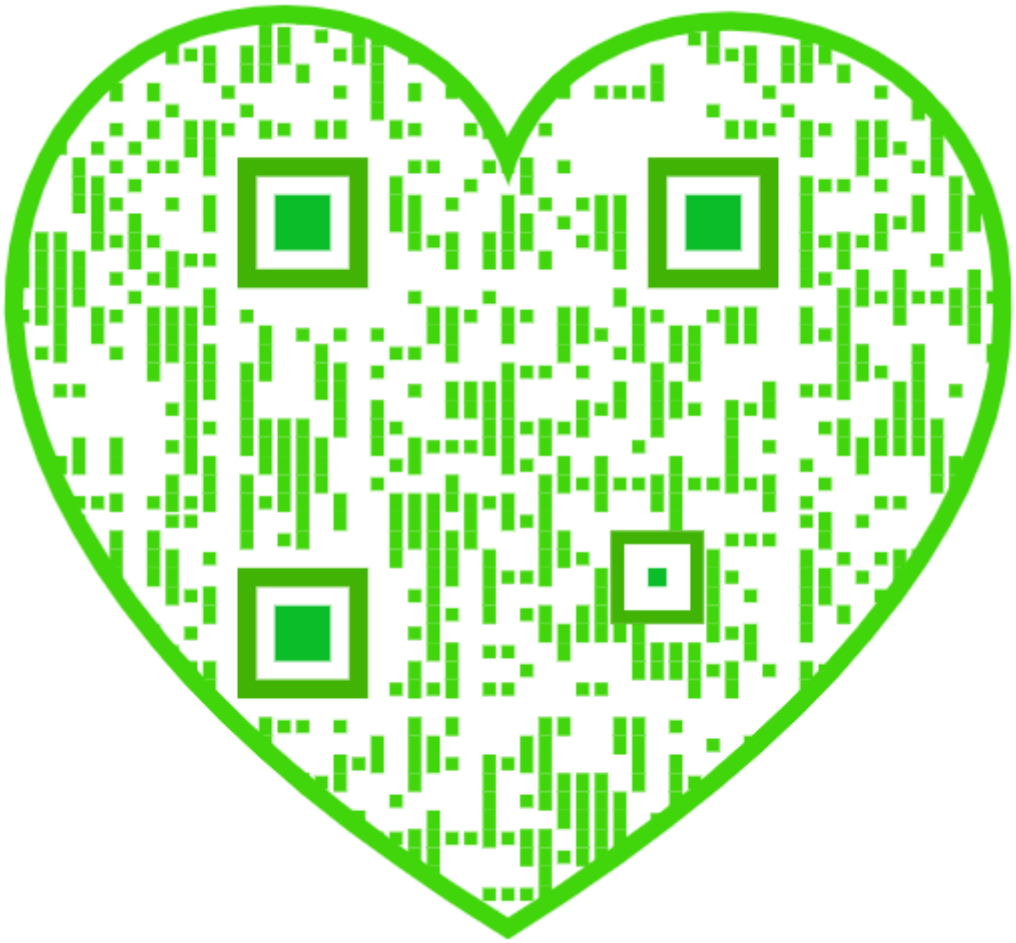
MAP READING AND TOPOGRAPHICAL SKETCHING

STUART



MAP READING
AND
TOPOGRAPHICAL SKETCHING

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BY

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PREFACE

In this book the author has attempted to record for the benefit of others something of the results of thirteen years of experience in the practice and teaching of topographical surveying and sketching.

There is no short cut to excellence in topographical work. Good maps result from the patient and careful labor of men thoroughly instructed in the means and methods of topographical representation.

WEST POINT, NEW YORK,
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AUTHORIZED ABBREVIATIONS

A.	Arroyo.
abut.	Abutment.
Ar.	Arch.
b.	Brick.
B.S.	Blacksmith Shop.
bot.	Bottom.
Br.	Branch.
br.	Bridge.
C.	Cape.
cem.	Cemetery.
con.	Concrete.
cov.	Covered.
Cr.	Creek.
cul.	Culvert.
D.S.	Drug Store.
E.	East.
Est.	Estuary.
f.	Fordable.
Ft.	Fort.
G.S.	General Store.
gir.	Girder.
G.M.	Grist Mill.
i.	Iron.
I.	Island.
Jc.	Junction.
k.p.	King Post.
L.	Lake.
Lat.	Latitude.
Ldg.	Landing.
L.S.S.	Life Saving Station.
L.H.	Light House.
Long.	Longitude.
Mt.	Mountain.
Mts.	Mountains.
N.	North.
n.f.	Not Fordable.
p.	Pier.
pk.	Plank.
P.O.	Post Office.
Pt.	Point.
q.p.	Queen-post.
R.	River.
R.H.	Roundhouse.
R.R.	Railroad.
S.	South.
s.	Steel.
S.H.	School House.
S.M.	Saw Mill.
Sta.	Station.
st.	Stone.
str.	Stream.
T.G.	Toll Gate.
Tres.	Trestle.
tr.	Truss.
W.T.	Water Tank.
W.W.	Water Works.
W.	West.
w.	Wood.

MAP READING
AND
TOPOGRAPHICAL SKETCHING

CHAPTER I

INTRODUCTORY

MAP reading and topographical sketching are essential tools of the military profession. Topography has an important influence over every military operation. Marches and tactical movements of troops are planned on maps, and the orders for military operations must in general be based upon some specific map. Such orders can be understood and intelligently carried out only by reference to an identical map. Thus throughout the entire chain of command in the military service a thorough understanding of maps is required.

Since topography is a governing consideration in military operations, it follows that topographical information which is unimportant in the civil uses of maps may be of the utmost importance for military purposes.

A *military map* is a map showing the topographical information which is important from a military point of view. Much of this detail is temporary in character, such as information concerning annual crops, details as to the character and condition of roads and bridges, etc., and therefore not shown on

ordinary topographical maps. Further, the minute detail, such as the smaller irregularities of the ground, fences, cuts and fills, etc., important from a military standpoint, can be shown only on maps of comparatively large scale.

Minute and temporary topographical detail means high first cost of survey and frequent revision, hence satisfactory military maps of any except possibly a very few important areas will not be available at the outbreak of the war. Practically all nations have completed or are working on general topographical maps of their territory. These are mainly for civil uses, and of too small a scale to be satisfactory for military purposes. The general topographical map of the United States is being prepared by the U. S. Geological Survey, and is on a scale of about one inch to one mile. It is fairly representative of the general character of maps available at the outbreak of the war, or in operations where the forces are shifting position rapidly.

But modern experience shows that war has a tendency to settle down into a series of protracted struggles more or less stationary in character. When such a situation arises, time becomes available for the expansion of the scale and detail of the maps of the areas involved. Furthermore, the character of the operations resulting from such a situation demands the use of maps in great detail and of a high degree of accuracy. Military forces may therefore be called upon to expand the scale of existing maps or even to create new maps for their own use during active operations.

Thus there is required in the military profession not only the ability to read maps, but also the ability to make them. The ability to read maps must be exercised by all grades down to include the non-commissioned officer. The bulk of the work of making maps will fall upon those specially trained and organized for this purpose. But every non-commissioned officer and junior officer should be able to make a sketch which will show accurately the detail of his own surroundings.

Study and practice will give the ability to interpret in a purely mechanical way the topographical symbols on a map. But only by learning to make maps can be acquired that intimate understanding necessary to enable one to interpret and evaluate the topographical information embodied in a map. One who has had experience in topographical work in the field will know from the map where the topographer has been and where he has not been; will know where the map is accurate and where only approximate; will know how much generalization and inaccuracy exist even in the best topographical maps; will know how much the generalization and inaccuracy are affected by the scale of the field work; and will be able to recognize by the topographical " expression " of a map the work of a competent topographer and equally unerringly the work of an incompetent one.

The ability to read maps does not require an extensive course in topographical surveying, but it does require the study of topographical features on the ground itself, and practice in the representation of these features with the degree of accuracy and detail possible on various scales. Such practical work can be carried out satisfactorily with comparatively crude equipment, because the faculty to be cultivated is that of representing the topographical features about a given point. The more or less mechanical manipulation of instruments by which a point is located is of much less importance.

CHAPTER II

MAP READING

Scales of Maps—Reading Scales

There are two essentially distinct elements in the art of reading a map:

1. The ability to interpret in a mechanical way the information to be found on a map.
2. The ability to weigh the topographical evidence given by a map.

Mechanical interpretation of the information recorded on a map requires familiarity with the scales of maps; familiarity with all of the conventional topographic symbols used in recording data on maps; and familiarity with the conventional methods employed in representing the form of the surface. This knowledge of map reading can be acquired by indoor theoretical work, preferably supplemented by study of models in connection with maps as an aid to visualization and clear comprehension of the ground forms represented.

To be able to weigh the topographical evidence given by a map, practical experience in the work of representing ground on a map is necessary. Only by work on the ground will it be thoroughly understood how utterly impossible it is to locate by measurement every feature shown on a map, and how much of the data even on the best of topographical maps rests upon the estimate of the topographer. Even in the largest scale maps the representation is still very small compared to the area represented. The difficulties, generalizations, and approximations of topo-

graphical representation can be thoroughly appreciated only by one who has familiarized himself with the methods used in making maps, and has actually attempted in practice to represent ground on paper. In this practice, a sharp distinction will be encountered in the accuracy of representation in plan as compared to that of the representation of ground forms.

Before attempting the representation of ground on paper, however, familiarity with the conventional methods of representation is necessary. This portion of the subject, which covers also the mechanical element of map reading, will accordingly be discussed first.

Scales of Maps

One of the most frequent uses of a map is to determine the distance between points on the ground represented. In order to furnish this information, distances between points on the map must bear a constant relation to the distances between the same points on the ground. This relation of map distance to ground distance is known as the *scale* of the map. The term has exactly the same significance as in all other drawings.*

It is well to emphasize the idea that the scale of a map is a simple matter of ratio of distances. The apparent complexity of the subject arises from the fact that, even in the case of large scale maps, the map distance is a matter of inches, whereas the ground distance is a matter of yards or even miles. Consideration of the subject of scales of maps therefore requires a conception of the ratio between very short and very long distances.

* The earth is spheroidal in form, and the absolutely accurate representation of its surface on a plane is impossible. Many forms of map projection have been devised to reduce this distortion to a minimum and it is negligible in the projections in ordinary use. The discussion of the subject of map projections and all other difficulties in map making resulting from the curvature of the earth belongs to treatises on geodetic surveying.

The first difficulty that presents itself is due to the fact that our conception of short distances is in inches, of moderate distances in yards or as a fraction of a mile, and of longer distances in miles. Thus a certain short distance may be readily recognized as 3 inches, but only in map reading and map making are we forced to learn to recognize 3 inches as $\frac{1}{21,120}$ of a mile. Nor does 1,584,000 inches convey a definite impression of distance until the mind has become accustomed to thinking of a mile as 63,360 inches, and we learn that the given distance is 25 miles.

The second difficulty lies in the fact that in topographical surveying distances are measured, not in inches or miles, but in feet or rods; and in topographical sketching distances are measured in still other units, in strides (=double paces) of the sketcher, or by timing a horse at a gait of known rate.

This confusion of units makes it necessary to use two different classes of scales for maps:

1. *Reading scales* for the purpose of ascertaining the ground distances corresponding to distances measured on the map; and
2. *Working scales* for the purpose of plotting on the map distances which have been measured on the ground.

Reading Scales.

A reading scale is a graphical scale which, when applied to a map, reveals to us the distances between points in units that we understand. For one accustomed to our units of measure, the reading scale may give short distances in feet or yards, but must give longer distances in miles and fractions of miles. Reasonable familiarity with the metric system enables one to use a kilometer scale, but such use is generally accompanied by a mental calculation of the distance in miles by multiplying by $\frac{5}{8}$ or .6.

The ordinary form of reading scale is shown in Fig. 1, in which the major graduations read miles and the extension quarters and eighths, these being the familiar subdivisions of a mile. A reading scale of kilometers would show kilometers as the main divi-

sions, with the extension subdivided decimally to agree with the metric system. Reading scales of yards are useful mainly in connection with infantry and artillery fire, and therefore applicable generally only to large scale maps. The main divisions represent 100 or 1,000 yards, and the extension is subdivided into decimal parts of the main divisions.

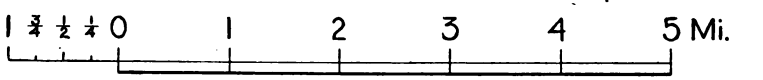


Fig. 1.—Typical Reading Scale.

To permit a more accurate measurement of distances, recourse may be had to the construction of a diagonal scale. Such a scale is used principally for the decimal subdivision of the smallest division of the regular scale. The principle of the construction of a diagonal scale is shown in Fig. 2. Parallel to the line of the

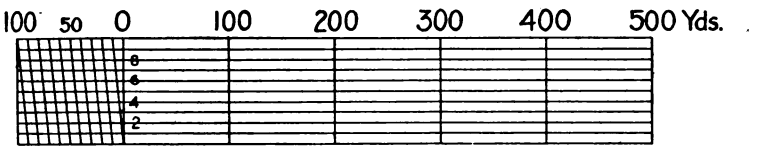


Fig. 2.—Diagonal Scale.

main scale are ruled ten lines with any convenient equal spacing. The ten subdivisions of the main scale are repeated on the last line, and the extension completed by joining the subdivision points as shown. A scale so prepared has a least reading $\frac{1}{10}$ of the smallest subdivision of the main scale.

A diagonal scale is of little practical value in measuring distances from maps, because its use assumes a higher degree of accuracy than most maps possess. For all ordinary military purposes the least reading of a direct scale is sufficient.

Methods of Stating Scales on Maps.

All maps should either have printed upon them their own reading scales, or else show the data necessary for the preparation of a reading scale.

The data with respect to the scale of the map may be given in one or more of three ways:

1. As a ratio between the map distance and the corresponding ground distance, expressed as a fraction called the *representative fraction* (abbreviated R.F.), written $\frac{1}{10,000}$, $\frac{1}{21,120}$, $\frac{1}{63,360}$, etc. The numerator of the R.F. is the distance on the map, and the denominator is the corresponding distance on the ground, both expressed in the same units. The first fraction means that 1 unit distance (inch, centimeter, etc.) on the map represents 10,000 of the same unit distances (inches, centimeters, etc.) on the ground. To those accustomed to the metric system, it means that 1 centimeter on the map represents 10,000 centimeters or 100 meters on the ground, and enables the regular centimeter scale to be used for scaling distances from the map. In our own units, a scale of $\frac{1}{10,000}$ means that 1 inch on the map represents 10,000 inches $= 833\frac{1}{3}$ feet, $277\frac{7}{9}$ yards, or .1578 mile,—all of which are odd distances bearing no relation to our usual conception of distances.

2. As a *simple statement* of the relation between map distances and ground distances, both expressed in some familiar unit: as 1 inch = 1 mile, 6 inches = 1 mile, 1 inch = 100 yards, etc. If the statement is given in some unit with which we have not a working familiarity, it must be translated into our units before it is of practical use.

3. As a *graphical scale* drawn on the map and so subdivided that the usual units in which ground distances are measured are represented in map distance by the subdivisions of the scale. Thus on a scale of 1 inch = 1 mile, the subdivisions of the graphical scale would be 1 inch in length, but the subdivisions would be designated 1, 2, 3, etc., miles.

Comparison of Methods of Stating Scales.

The persistence of three different methods of expressing the scale of a map is explained by the fact that each has certain advantages not possessed by the others. The R. F. is a statement of ratio which is independent of the unit used, and enables any one to construct a reading scale for the map in units with which he is familiar.

The actual ratios used as the scales of maps are dependent upon the units familiar to those who make and use the maps. Thus the convenient ratios for those familiar with the metric system are all decimal, as $\frac{1}{5.000}$, $\frac{1}{10.000}$, $\frac{1}{20\,000}$, $\frac{1}{40.000}$, $\frac{1}{80.000}$, $\frac{1}{100.000}$, etc., because these ratios give directly the relation between the small units of the ordinary metric scale in which map distances are measured and the large units in which ground distances are measured. In fact, a representative fraction such as those written above gives directly all the information necessary to use an ordinary centimeter scale for the purpose of reading distances in kilometers from the map.

For the same reasons that cause the use of decimal ratios in the metric system, we are forced to use in our maps a system of representative fractions running $\frac{1}{5.280}$, $\frac{1}{10.560}$, $\frac{1}{21.120}$, $\frac{1}{31.680}$, $\frac{1}{63.360}$, etc., because these are the ratios which obtain when inches on the map represent familiar fractions of a mile on the ground, thus enabling us to use an ordinary scale of inches as a reading scale for our maps.

From the above discussion, it is seen that the ratios expressed by the representative fractions of maps are inseparably connected with the units of measure familiar to those for whose use the maps are principally intended, and that those ratios convenient for one system are inconvenient for another.

However, if the representative fraction is recorded on a map, it furnishes the data for the construction of a reading scale in any system of units of measure, and is therefore generally regarded as an essential piece of information to be entered on a map.

The simple statement of the relation of map distance to ground distance merely tells how to use an ordinary scale for measuring distances on a map. The simple statement is simple only as respects the system of units of measure to which the scale of the map is conveniently related. Thus a statement that the scale of a map is 1 inch = 1 mile is good news to one provided with an inch scale and familiar with ground distances in miles, but it does not help much to know that the scale is one centimeter = one kilometer unless we have a centimeter scale and are familiar with ground distances in kilometers.

It is manifest that a graphical scale whose subdivisions represent ground distance units with which we are familiar is, after all, the only reading scale that is convenient for our use. Such a scale is more convenient if detached from the map, but there are two good reasons for printing a graphical scale on a map. One is that it will not be lost or missing when wanted, and the other is that it forms a record of the scale of the map which remains correct if the map is enlarged or reduced by photographic means. If the scale is given either by R.F. or by simple statement, the data are falsified by photographic enlargement or reduction, hence it is very desirable that the map shall bear on its face a graphical scale, even though the scale is also stated or the R.F. given.

To be convenient for our use, a map must bear a graphical scale in our own units, or must be drawn to a scale conveniently related to our units. In the latter case, an ordinary foot rule forms the desired detached scale for use in measuring distances on the map. But if neither of these conditions be fulfilled, then it is necessary to construct a graphical scale suitable for the map to be used.

Construction of Graphical Reading Scales.

If the scale of the map is in some unfamiliar unit, it is necessary that the data with respect to the scale be in some form that makes it possible to determine the R.F. of the map. Thus if we

assume a Russian map with a graphical scale of versts printed on it, we could measure directly the length of the divisions representing versts, but could proceed no further unless we happened to know that a verst is 3,500 feet. However, the difficulty of obtaining a great deal of useful information from a map with the names printed in Russian characters suggests that the discussion be confined to the more usual case of maps based on the metric system. These maps practically invariably show the representative fraction of their scale. If not, remembering that one meter = 39.37 inches, a careful direct measurement of the graphical kilometer scale will serve to reveal the R.F., especially as the denominator is certain to be some multiple of 1,000, except in the scale R.F. $\frac{1}{2,500}$.

Example 1. Let us assume that the R.F. of the map has been determined to be $\frac{1}{80,000}$, showing a scale smaller than 1 inch = 1 mile. Let it be required to construct a reading scale of miles.

Solution. In this case it will be desirable to construct a reading scale with 1 mile as the main division, and showing 10 miles on the main scale and 1 mile on the extension, or 11 miles total length. Eleven miles = $11 \times 63,360$ inches = 696,960 inches. With R.F. $\frac{1}{80,000}$, the map length of 11 miles would be $696,960 \div 80,000 = 8.712$ inches, which is the total length of the scale to be constructed. Draw a line and lay off by scale 8.712 inches as nearly as practicable. Divide this by the usual oblique geometrical construction into eleven equal parts, and subdivide the left-hand division into eighths by the same construction. This construction is shown (not to scale) in Fig. 3. The equal divisions on the oblique line are laid off by an inch scale and projected back on the line to be subdivided by lines parallel to the line B C.

Example 2. Assuming a map scale of $\frac{1}{20,000}$, let it be required to construct a reading scale of yards for this map.

Solution. One yard on the map represents 20,000 yards on the ground, hence 1,000 yards will be represented by $\frac{36}{20}$ of an

inch = 1.8 inches, hence we select 1,000 yards as the main division of the scale. A reading scale showing 6,000 yards will therefore be 10.8 inches long. By a construction similar to that shown in Fig. 3, divide a line 10.8 inches long into six equal parts. Subdivide the extension into ten equal parts. The main scale will show five divisions each representing 1,000 yards, and the extension 1,000 yards with a least reading of 100 yards. If a diagonal scale be constructed as in Fig. 2, the least reading will be 10 yards.

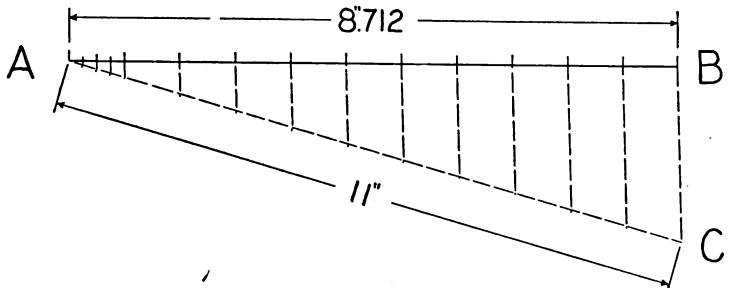


Fig. 3.—Division of Scales.

Rules for the Construction of Reading Scales. In general, to construct a reading scale:

1. Determine the R.F. of the map. If this determination results in a near approximation to a decimal ratio or to one of the fractions representing the inch-to-mile ratios, it should be assumed that the actual ratio is the nearest decimal or inch-to-mile fraction.
2. Select as the main division of the scale a convenient unit, as 1 mile, 5 miles, 100 yards, 1,000 yards, such that the main division will be not less than about $\frac{1}{2}$ inch in length. For large scale maps, the main scale and the extension may each represent 1 mile.
3. Determine a convenient number of main divisions of the scale such that, with one division added for the extension, the total length of the scale will be between 6 and 12 inches.

4. Calculate the total length of the scale.
5. Subdivide into the proper number of divisions, and subdivide the extension into convenient fractions of the main divisions.
6. Mark the divisions of the scale properly.

Problems in the Construction of Reading Scales.

Problem 1. Construct a reading scale of miles and fractions of miles for a map scale of $\frac{1}{20,000}$.

Problem 2. Construct a reading scale of yards for a map scale of $\frac{1}{5,000}$.

Problem 3. Construct a reading scale of yards for a map scale of 6 inches = 1 mile.

Problem 4. A kilometer reading scale is shown on a map. The distance representing 10 kilometers measures scant 4 inches. Construct a reading scale of miles and fractions.

Problem 5. A certain distance is measured on the ground and found to be 3 miles. The corresponding map distance is $4\frac{3}{4}$ inches. Construct a reading scale of yards.

CHAPTER III

MAP READING—Continued

Scaling Distances on Maps

Methods of Scaling Distances.

Straight Lines. Straight-line distances may be measured by applying a graphical reading scale directly to the map, or by measuring the distance with a pair of dividers or on the edge of a piece of paper, and then applying the length so found to a graphical reading scale.

Meandering Lines. Meandering lines may be measured in several different ways:

(*a*) Directly by applying the scale successively to short lengths, each of which approximates to a straight line, and summing the total distance measured.

(*b*) The total length may be accumulated on a pair of dividers by setting the dividers at the initial point and measuring the first portion approximating a straight line; then swinging the rear leg of the dividers into prolongation of the next portion of the line to be measured and setting the rear leg on the paper; then extending the forward leg to the new forward point, and so continuing until the total distance is accumulated. Then apply the dividers to the scale.

(*c*) By a process similar to (*b*), successive distances may be accumulated along the edge of a sheet of paper, and the total distance applied to the scale.

(*d*) For continuously curving lines, a thread or string may be made to conform to the line, and the total length thus determined applied to the scale.

(*e*) An instrument called a "map measure" is sold by instrument dealers. It is provided with a contact wheel which when rolled over the map, records by a pointer and dial the distance in inches passed over. The map measure may be used on straight lines, but is particularly convenient for measuring sinuous lines.

If the scale of the map is in inches-to-the-mile, the map measure reveals the ground distance directly. For other scale ratios, the map measure must be rolled backwards over the divisions of the graphical scale to determine the ground distance. In this process, the map measure must be rolled over such numbers of even divisions that from the dial it becomes evident that one more division will cause the pointer to pass the zero. Then it is rolled over the extension scale until the pointer reaches zero to determine the fractional part of the reading.

Accuracy of Distances Scaled from Maps.

Measurements of distances on maps are made for two principal purposes:

(*a*) Along roads for determining the distances between towns, the points which marching columns will reach at given times, and for various purposes in connection with the movements of troops and transport.

(*b*) Along straight lines for the purpose of determining ranges for artillery and infantry fire.

Measurement of Distances along Roads. As a general rule, the location of roads may be considered the most accurate data shown on a map, for the reason that convenience in surveying work of any kind demands that the roads shall be located and plotted accurately to serve as a basis for the rest of the work. Even in topographical sketching, the roads are plotted as accurately as sketching methods permit, and road distances on such sketches may be relied upon as being within a maximum limit of error of about 2 per cent.

Although the distances along roads are thus generally reliable in all classes of maps, the military purposes for which distances are scaled from the roads do not demand a high degree of accuracy. An error of a quarter or half mile in a distance of ten miles is of little importance in connection with marches of troops or movements of transport, because there are so many other elements of uncertainty in such operations that great accuracy of calculation is unnecessary and undesirable.

Problem 1. From Plate A, what is the road distance from the center of the bridge over the Red River to a point opposite the northeast corner of the reservoir?

Problem 2. From Plate A, what is the distance by road from the bridge over Indian Creek east of the Water Works to the school house (S. H.) at Weston?

Other Exercises. Use maps of as many different scales as may be available. Select on roads points which could be easily identified on the ground.

(*a*) Measure the road distance between points.

(*b*) Compare the distances between points by various routes.

(*c*) Find how long it would take to travel from one point to another at an assumed rate.

(*d*) Assume that a column of troops 1½ miles long with leading element at a certain point begins a march at 2½ miles per hour along a selected road at 7.15 A. M. Find the time when the leading element of a column 2 miles long would have to leave another selected point in order to cross the line of march of the first column just before the first column reached the cross road, or just after it had passed.

Measurement of Artillery and Infantry Ranges. The measurement of ranges from maps presents an entirely different problem from that of measurement of road distances. Two factors enter.

(*a*) The accuracy of the measurement as a mechanical process; and

(*b*) The accuracy of the location and identification of the points on the map between which the measurement is made.

The mechanical part of the measurement of the distance between points marked on the map offers little difficulty, assuming that the map is in good condition and lying flat on some suitable surface, and that the points between which the distance is to be measured are both on the same map sheet. It is then only necessary to measure the straight-line distance carefully and apply this distance to a carefully constructed reading scale. Since it is desirable to ascertain range distances as accurately as possible, it is preferable to use a diagonal scale for the purpose.

However, maps in use in the field require special care to insure their good condition. On all maps that are fit for use for the purpose of measuring ranges, it may be assumed that the data are as accurately plotted with reference to the lines of the map projection as possible. If the separate squares or rectangles of the map determined by the map projection lines be made to conform to an accurate reproduction of the same projection lines on a suitable and as nearly as possible unchangeable surface, the map will be in the best condition possible for use. This is accomplished by preparing an accurate reproduction of the map projection lines on a sheet of zinc. The lines are scratched on by a sharp steel point. The map is now cut into the squares defined by the projection lines and each square is carefully pasted within the proper area defined by the projection lines scratched on the zinc. This insures that the worst distortion in the whole map shall be that due to the application of a single small section of the map in its proper place on the sheet of zinc.

Furthermore, the method just described permits the assembling of portions of different map sheets into a continuous map, the parts of which are as accurately related to each other in direction and position as if they had been on the same map sheet. Maps so mounted are frequently used, particularly for artillery purposes.

Assuming a properly mounted map, the distance between two points on the map can be measured accurately. Whether or not the distance thus measured represents accurately the distance

between two points on the ground depends upon the accuracy with which the map positions of the points have been identified, because the map distance will be in error if the assumed map position of either point is wrong.

The accuracy of ranges measured on a map thus depends upon the accuracy with which the map positions of points on the ground are identified, and this in turn depends upon a knowledge of how maps are made.

Instead of measuring ranges directly from the map, they may be calculated from the coordinates of the points.

Map Positions of Points on the Ground.*

All points on a map are not located and plotted with the same degree of accuracy. It is therefore desirable to know which points are located exactly and which only approximately.

Triangulation Points. In general, all formal surveys are controlled by a series of points located very accurately by triangulation. These triangulation stations are located at points from which a wide view can be had, and are consequently to be found on the tops of prominent hills. The stations themselves are marked permanently on the ground so that they can always be identified. On the resulting maps, the triangulation stations are marked by points with small triangles drawn about them. Any point so marked on a map may be relied upon absolutely as being accurately plotted in position. Any point near a triangulation station should be referred to the triangulation station by proper measurements if the accurate map location of the point is desired.

Points along Roads. Connecting the triangulation points of a survey are run a series of traverses covering usually the roads offering the best and most direct routes between stations. These traverses are corrected by the known positions of the triangu-

* This paragraph should be read again after some practice is had in map making.

lation points, and constitute the next most reliable data on the maps. Traverses are then run covering the remaining roads, corrected to fit the traverses between triangulation stations. All of these traverses are usually run by instrumental methods, and are to be relied upon in order of nearness to the triangulation stations.

Although the roads themselves are thus reliable in their locations, it is necessary to be cautious in identifying points along the road. If a house or bridge is plotted, it is safe to assume that a measurement has been taken to it and that it has been accurately plotted. But a topographical feature such as a spur of a hill or a patch of woods cannot be relied upon, because it is probable that it has been located only approximately.

The only certain method, therefore, in locating and plotting the position of a point on a road is to measure on the ground the distance from some other point which can be positively identified on the map and ground, and then set off this distance on the map. On battle maps for the use of artillery, points along all main roads traverses should be described and listed with sufficient data to enable the points to be located both on the ground and on the map. Such a list will enable other points on the map to be located by suitable measurements from these known points. Descriptive lists of points on the road traverses are actually issued for use in connection with most, if not all, of the European battle maps.

Interior Points. For points in the interior areas, it is necessary to exercise still more caution in accepting the plotted position. In making maps, it is impossible to locate all points by actual measurement. Thus only a few points on a stream course are located and the stream is then drawn in by estimating the meanderings between located points. Many other topographical features must of necessity be located by estimation from known points and lines. When familiarity has been gained by practical experience with the methods used in making maps, it is possible to judge with considerable accuracy just where the topographer

went and what points he located by actual measurement, but there will still be the question of whether specific points which it is reasonably certain that he located accurately are actually plotted on the map. Suppose the point to be considered is the plotted position of a house at a distance from the road. If the house is visible from two points on the road, which were probably used as stations on the road traverse, it is quite certain that the house has been located by intersection, and therefore its plotted position corresponds in accuracy with a point on the road traverse itself. Furthermore, it is certain that the house itself can be found on the ground.

But if the point be a hilltop, then the accuracy of its location will depend to a large extent on its visibility from points on the road traverse, and further upon whether there is on or near its summit some object such as a tree, bush, or rock which might have been used as a point of sight for intersections. If so, that object was probably located accurately by intersections, or a rodman may have been used in locating the point, but there remains the difficulty that it was not plotted on the map and its map location can only be judged by its relation to the top of the hill itself. In such case there may be a substantial error in judging the exact map position of any point on the top of the hill.

A knowledge of the methods of map making is thus essential to a correct judgment concerning the map location of any selected point on the ground. Such knowledge will lead to caution as to accepting points seen on the ground. The safe course generally is to plot the map position of any point by making the necessary measurements on the ground to establish its relation to some point or points which may be safely assumed to have been accurately located by the topographer, and which are actually plotted on the map. Then the desired point can be plotted accurately on the map.

So far as battle maps are concerned, the above discussion applies principally to points within our own lines, and refers

especially to the plotting of positions of batteries and machine guns.

Ranges are measured from these points to the targets, which lie behind the enemy's lines. As a matter of fact, practically all the details within the enemy's position are plotted from airplane photographs, and a target becomes known if it is discovered on these photographs. In that case its position can be plotted accurately on the map from the photograph. There are also secret means of determining the positions of targets within the enemy's lines, but these cannot be described.

It must be assumed that the map positions of targets are plotted as accurately as possible from the best information available. Any errors in their map positions must be compensated for by corrections resulting from aerial observation of fire.

CHAPTER IV

MAP READING—Continued

Working Scales

In the process of making maps, it is necessary to be able to plot conveniently and accurately distances which have been measured on the ground. This involves the construction of a graphical scale showing map distances corresponding to the units of measure used in making the map, called a **working scale.** A working scale is in fact a graphical reading scale, differing in units but not in principle from the reading scales already described.

Measurement of Distances in Surveying and Sketching.

In topographical surveying, distances are measured on the ground in feet by the stadia or steel tape, sometimes (though rarely) by the surveyor's chain in rods and fractions. In military sketching, distances are measured by the dismounted sketcher in strides (double paces), and by the mounted sketcher in minutes and fractions by timing the horse at a gait of known rate. The unit of distance used in survey work is fixed. The length of the sketcher's stride or the rate of his horse must be determined before starting work, and should be checked from time to time while work is in progress.

Determination of Length of Stride. The length of the stride is determined by pacing over a measured course, counting each time the right or left foot strikes the ground. From the measured length of the course and the average number of strides determined by pacing the course a number of times, the average length

of the stride is computed. The length of the stride varies with the height of the man, but the general average is about 64 inches.

Although the process is thus simple, a considerable degree of care is necessary to secure satisfactory results. What is desired is a general average length of stride under the varying conditions to be encountered in sketching in the field. The necessary precautions are as follows:

(*a*) Select a course which includes slopes not exceeding about five degrees, and lies partly on roads and partly across country.

(*b*) Measure the course with a tape. Measurement along the surface will be sufficient.

(*c*) Pace the course several times in each direction.

(*d*) Guard against errors in counting the strides. A pace tally is made and sold by dealers, but its use is not recommended. The usual type is not entirely reliable, it forms an additional piece of equipment to be carried around, and it has the serious disadvantage of not being made of non-magnetic metal and is for this reason objectionable as likely to influence the magnetic needle of the sketching case. Learn to count always on the same foot. It is well to keep track of the hundreds of strides upon the fingers.

(*e*) Avoid being influenced by others who may be pacing the same course. Do not pace alongside or close to another person on account of the tendency to keep step.

(*f*) Do not try consciously to keep a uniform length of pace, but take a natural gait. As a sketcher you will be thinking of your work insofar as counting strides will permit, and will give no thought to the length of pace.

(*g*) Pace the course at the same gait that you will use in sketching. The length of the stride is affected by the speed at which you travel, and sketching is hard work involving much walking. Try to take the gait you would use in a long walk.

(*h*) Do not try to force the length of stride either up or down hill. What you are trying to secure is a general average stride length applicable to distances on slopes as well as on the level.

From the data determined under the above conditions, compute the average length of the stride in inches.

If desired, a single course may be laid out on a slope of about 10 degrees, and its horizontal length determined. Pace over this course up and down hill, keeping a separate record in each direction. These data should not be used in determining the average length of the stride, but in determining a percentage correction to the number of strides on steep slopes. Thus, if the average stride length is 64 inches, and the average horizontal stride length is 60 inches going up a 10-degree slope, it will be necessary to subtract $\frac{1}{16}$ of the number of strides taken in going up this slope to obtain the correct number of strides to plot with a 64-inch stride scale.

The reason for not using steep slopes in determining the average length of stride is that, as a general rule, pacing on steep slopes is avoided whenever practicable in sketching, and it is better to apply a correction in the few cases when pacing on such slopes is necessary.

Determination of the Rate of a Horse. When used in sketching, the horse will invariably travel on roads. For this reason, a portion of road conforming to the average of the country in grades and condition should be selected and measured as a rating course. The rate at a walk, trot, and gallop is desired in terms of minutes per mile of travel. The important gait for sketching is the trot.

It is to be remembered that the rider and not the horse is responsible for the rate of travel. If left to himself, the horse will proceed at variable speed, and will travel faster coming home than going in the opposite direction. Each horse has, however, a natural gait at a walk and trot which can be maintained by the rider more easily than any other. It is these natural gaits which are to be sought and maintained in rating the horse.

Having identified these natural gaits, the rider times the

horse over a measured course 1 to 2 miles in length, preferably with a stop-watch. The course should be repeated three or four times each at a walk and trot, to determine the average time per mile at each gait. The gallop is almost never used in sketching and hence may be omitted in rating the horse. Suitable alternation of walk and trot should be used in order to prevent undue tiring of the horse, which would affect the gait.

From the data secured as above described, the time per mile in minutes and fractions is computed for both the trot and walk.

Construction at Working Scales.

For purposes of illustration, it will be assumed that the length of stride has been determined to be 64.5 inches, and that the time of a horse has been determined to be $13\frac{1}{2}$ minutes per mile at a walk and $7\frac{1}{2}$ minutes per mile at a trot.

The best method of procedure is to find by calculation the exact map distance corresponding to some suitable whole number of measuring units. The latter number is to be so chosen that the actual map length of the working scale will be about 6 inches. Lay off the map distance on the line representing the scale, and on an oblique line suitable even divisions to represent the measuring units. Complete the scale by the method shown in Fig. 3.

Example 1. Required to construct a working scale of 64.5-inch strides for use in sketching on a map scale of 6 inches = 1 mile.

Solution. The stride length being 64.5 inches, 1,000 strides will be 64,500 inches, or $\frac{64,500}{63,360}$ of 1 mile. The map length of 1,000 strides will therefore be $\frac{64,500}{63,360} \times 6 = 6.11-$ inches. On the line representing the main scale lay off 6.11 inches, and divide this distance into ten equal parts by the method illustrated in Fig. 3. Subdivide the left-hand division into ten equal parts, and add one division on the right to complete 1,000 strides on the main scale.

The main divisions of the scale will be 100 strides and the subdivisions of the extension 10 strides. Number the divisions.

Example 2. Additions and corrections are to be made on a map, scale $\frac{1}{20.000}$. Construct a time scale for a horse which trots a mile in $7\frac{1}{2}$ minutes for use in this work.

Solution. The scale of the map in inches to the mile is $\frac{63.360}{20.000}=3.168$ inches. Hence a scale showing 2 miles or fifteen minutes of time of the horse will be of convenient length. The map length of 2 miles is $3.168\times2=6.336$ inches. Lay off this distance and subdivide it into 15 equal parts, each of which will represent one minute at the trot. Add one division for the extension, and divide it into quarters. The subdivisions will represent fifteen seconds.

Example 3. Construct a 64.5-inch stride scale for use in plotting positions on a map of scale $\frac{1}{10.000}$.

Solution. The length of 1,000 strides is 64,500 inches, and the map length of 64,500 inches on a scale of $\frac{1}{10.000}$ is $\frac{64.500}{10.000}$ $=6.45$ inches. Lay off 6.45 inches and subdivide into ten equal parts, each of which will represent 100 strides. Add one division and subdivide it into ten equal parts, each representing 10 strides for the extension.

Example 4. Construct a working scale for stadia readings in feet for use in plotting points on a map of scale $\frac{1}{5.000}$.

Solution. On this scale, 1 foot on the map will represent 5,000 feet on the ground; hence the scale length of 3,000 feet will be $\frac{3.000}{5.000}$ of 12 inches $=7.2$ inches. Lay of 7.2 inches and divide into three equal parts. Subdivide the left division into ten equal parts and then construct a diagonal scale according to the method illustrated by Fig. 2. The least reading from the diagonal scale will be 10 feet.

Problems in the Construction of Working Scales.

Problem 1. Construct a working scale for 62.5-inch strides for use in sketching on a scale of 12 inches $=1$ mile.

Problem 2. Construct a working scale of 64-inch strides for work on a map of scale 1 inch = 100 yards.

Problem 3. Construct a walk scale of minutes for a rate of fourteen minutes to the mile on a map of scale $\frac{1}{30,000}$.

Problems Involving Erroneous Scales.

A great variety of problems may be stated involving the effect of the employment of erroneous working scales upon the reading scales of maps. However the data may be given, they are always susceptible of being reduced to the form that the stride length or the rate of the horse was supposed to have a certain value at the time the map was made, whereas it was in some way discovered later that the value was erroneous.

No matter how these problems are stated, it is always possible to calculate the erroneous stride length or the rate of the horse used in making the map, and the later ascertained true value of these units. The original erroneous construction of the working scale can be reproduced, thus showing the actual distances plotted on the map corresponding to strides or minutes actually counted in making the map. The revised data can always be used to calculate the true values of the strides or minutes, and the correct number per mile. The plotted length of this number of strides or minutes can be determined by interpolation on the construction of the false scale, and its projection on the main scale will show the true map length of 1 mile, from which a correct reading scale can be constructed. It is safer to solve these problems in this way than to attempt to establish by reasoning the ratio between the false and true scales, because of the inverse ratio between length of stride and number of strides per mile.

Example. The stride length was calculated from a measured course and found to be 63 inches. A working scale of strides was then constructed and used in making a map on a scale of 6 inches = 1 mile. Failing to check accurately on some known

distance, the course was repaced and the correct stride length was found to be 65 inches. What was the correct scale of the map?

Solution. If the original construction of the stride scale be reproduced, it will show that $\frac{63.360}{63} = 1{,}006$ strides were considered as 1 mile and actually became 6 inches on the working scale. The later data show that $\frac{63.360}{65} = 975-$ strides actually covered 1 mile. The plotted length of 975 strides is the true value of 1 mile on the map, which is $\frac{975}{1.006} (= \frac{63}{65})$ of 6 inches = 5.8+inches.

Problem 1. Over a measured course believed to be 6,235 feet long, the length of stride was determined to be 64 inches. The resulting stride scale was used in making a map on a scale $\frac{1}{10.560}$. It was later discovered that the correct length of the course was 6,325 feet. What was the true scale of the map?

Problem 2. The rate of a horse had been determined to be 1 mile in $7\frac{1}{2}$ minutes, and a working scale constructed for use at 3 inches = 1 mile. Two weeks later the same working scale was used in sketching, but the horse was slightly lame. By mile posts on a road traversed, it was noted that a mile was covered in eight minutes twenty seconds. What was the correct R. F. of the sketch made that day?

CHAPTER V

MAP READING—Continued

Conventional Signs

Conventional Signs on Topographical Maps.

A TOPOGRAPHICAL map suitable for military use should show the railroads, roads, trails, paths, large streams, and canals, all of which are important as means of communication; cities, towns, villages, and isolated houses, important as indicating possible sources of supplies of all kinds and shelter for troops; smaller streams, lakes, ponds, large springs and wells, important as sources of water supply for troops and animals; woods, orchards, growing crops, and grass land, important as indicating sources of supplies of fuel and possibly of food, and still more important as offering concealment for troops or possible obstacles to the movement of enemy troops; and the form of the ground, which is all-important as affecting the disposition of troops for battle.

All of these topographical features are represented on maps by appropriate conventional signs. These conventional signs are designed to form a clear and easily interpreted record of the topographical data. Simplicity of signs is desirable as a matter of economy of time in drawing, as well as on account of clearness of the resulting map.

On account of the relatively small scale of even the so-called "large-scale" maps, it is desirable that the conventional signs should be capable of readable execution in small space, in order that a maximum of data may be entered upon the map.

A standard system of conventional signs is desirable in order that any map that comes to hand may be used without danger of confusion or misinterpretation. The need for uniformity in representation is such that practically all nations have adopted standard systems of conventional signs which are required to be used in the preparation of all maps issued by the different departments of the government.

Although each nation has thus a standard system of conventional signs, the desire for uniformity has not yet secured the adoption of any international standard, and the conventional signs differ on maps of different countries. There is a general agreement in the signs for the principal features, such as roads, streams, cities, etc., but even these differ in detail, so that it is necessary to know the particular conventional signs used on the map under consideration. Very frequently the standard set of conventional signs used is printed either on the margin or on the back of the map itself, where reference is easy. If not, it is always possible to procure in sheet or pamphlet form a complete set of the conventional signs used in any set of topographic maps.

For our own maps, a standard set of conventional signs has been adopted by the United States Geographic Board for use by all map-making departments of the government. These signs have been published in War Department Document No. 418, which can be obtained from the United States Geological Survey Office, Washington, D. C. For convenience, the principal ones of the topographical conventional signs are repeated in Figs. 4–15 inclusive, at the end of this chapter.

Special Military Symbols.

In order to record upon maps the position of troops, batteries, machine gun emplacements, searchlights, and the multitudinous other things that play their parts in modern military operations, it has been necessary to expand very greatly the

previous list of special military symbols, and further additions are necessary at frequent intervals. So rapidly is this list expanding that it is necessary to procure an up-to-date set of the special signs for the particular maps being used in order to guard against mistakes. For that reason, none of the special military symbols is repeated here.

Color Conventions.

There is a great gain in the clearness of maps by the use of different colors to represent different classes of information, as will be seen by reference to Plate A. Three colors are generally used on small scale topographical maps on which no vegetation is shown, and four on large scale maps showing vegetation. On battle maps, two additional colors are used—one to show the military positions and works of the enemy and the lettering pertaining thereto and another for those of our own troops.

The color conventions are as follows:

Black for the works and constructions of man, such as railroads, roads, telegraph and power lines, bridges, ferries, fords, cities, towns, villages, buildings, fences (except hedge), state and other municipal boundaries, for the lines of map projection and map reference, and also for all lettering except such as pertains to special military symbols.

Brown for natural and artificial ground forms, including contours and contour numbers, cuts, embankments, levees, sand banks and dunes, gravel banks, rocks, and for the embankment sign in the rice symbol.

Blue for all water features, such as oceans, bays, lakes, ponds, streams, canals, aqueducts, pipe lines, drainage and irrigation ditches, marshes, swamps, and glaciers.

Green for all vegetation symbols.

Special colors, one for all enemy forces and military works and lettering pertaining thereto, and another for our own.

These color conventions have been regularly used when the conditions attending the publication of maps permitted, as for

example in the maps of the United States Geological Survey. Maps are of such great importance in modern war, and are used in such great numbers, that the elaborate organization and plant necessary for the rapid printing of maps may be regarded as essential. On account of the additional facility in reading maps gained by the use of different colors, provision has also been made for printing even the battle maps in color. The use of color in military maps may therefore be regarded as the rule and not the exception.

Relation of Conventional Signs to Map Scales.

Since topographical data are recorded in the form of conventional signs, and the scale of the map determines the space available in which to record the data concerning a given area, it is manifest that there is an intimate relation between the scale of the map and the use of conventional signs.

This subject will be discussed further in Chapter VII in connection with the interpretation of map data in general.

Familiarity with Conventional Signs.

The conventional signs given on the following pages should be memorized so that any one of them will be readily recognized, and that any one of them can be reproduced from memory. There will be many others to be learned when foreign maps are encountered, but those here given will suffice as a foundation for work in map reading and topographical sketching.

Exercise 1. Examine Plate A and see if all conventional signs used on it are recognized.

Exercise 2. Examine similarly any other topographical maps available. The special Plattsburg map, scale 3 inches = 1 mile, published by the United States Geological Survey, is especially suitable for this purpose.

Exercise 3. Ask someone to prepare a list of fifteen conventional signs from among those shown in Figs. 4–15 inclusive, and then draw all of these signs.

WORKS AND STRUCTURES

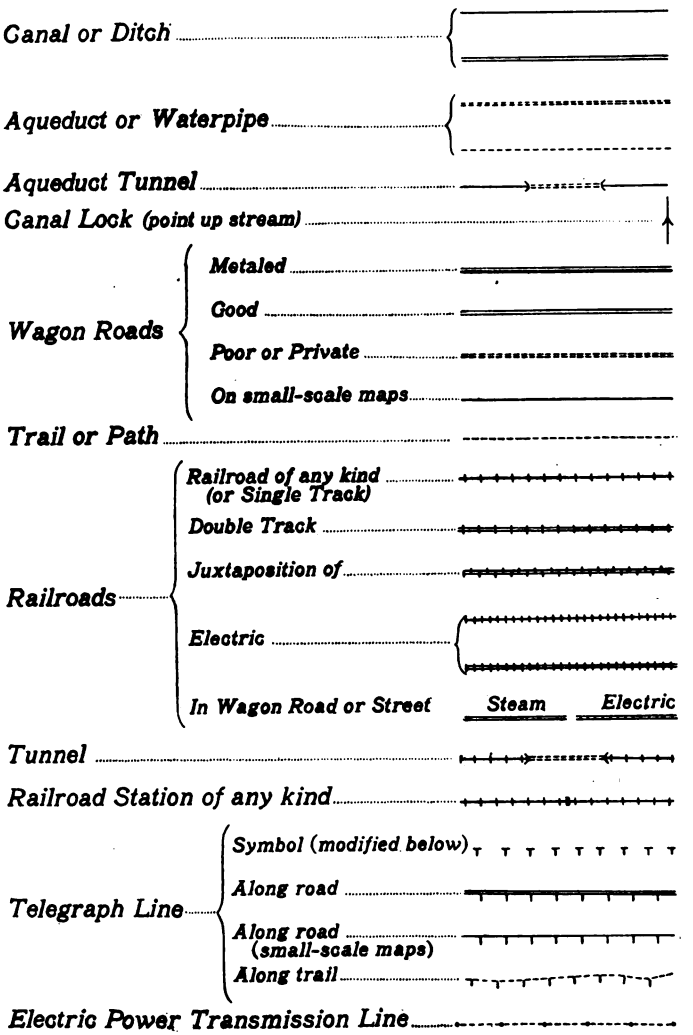


Fig. 4.—Conventional Signs.

WORKS AND STRUCTURES

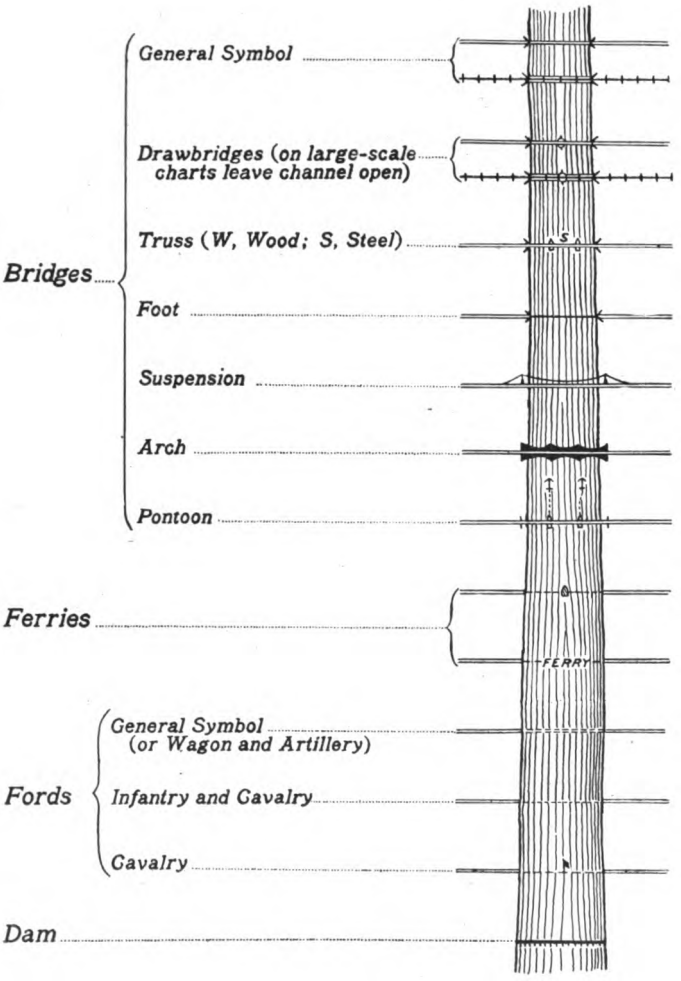


Fig. 5.—Conventional Signs.

WORKS AND STRUCTURES

Buildings in general

Ruins

Church ‡ or ✝

Hospital ·HOS

Schoolhouse ‡ or ·SH

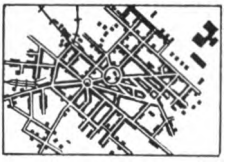
Post Office ·PO

Telegraph Office ‡ or ·TO

Waterworks ·WW

Windmill ⛥ or ⚹

City, Town, or Village



City, Town, or Village (generalized)

City, Town, or Village (*small-scale maps*)

- *Capital*
- *County Seat*
- *Other Towns*

Fig. 6.—Conventional Signs.

WORKS AND STRUCTURES

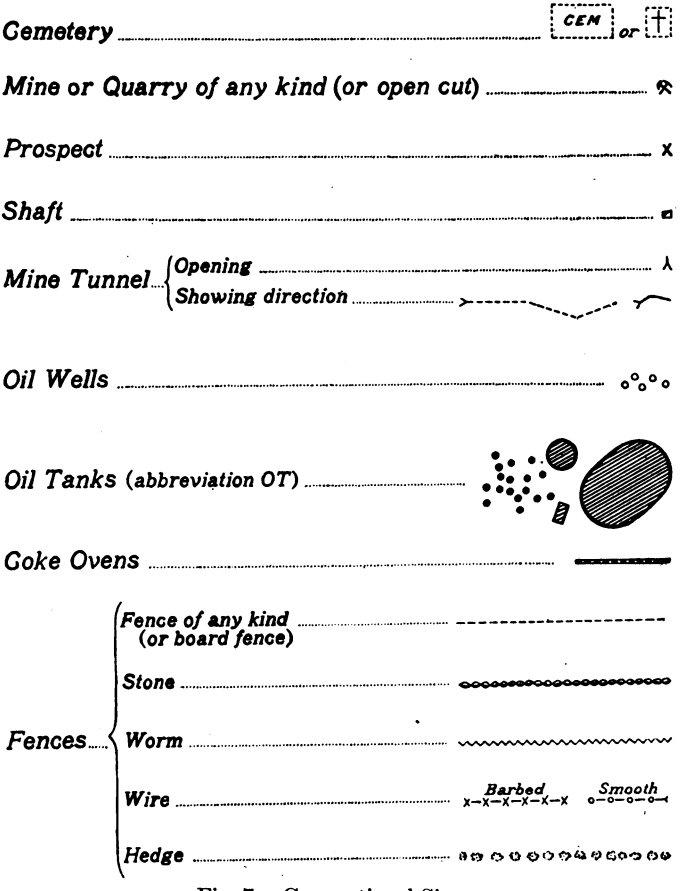


Fig. 7.—Conventional Signs.

BOUNDARIES, MARKS, AND MONUMENTS

National, State, or Province Line

County Line

Civil Township, District, Precinct, or Barrio

Reservation Line

Land-Grant Line

City, Village, or Borough

Cemetery, Small Park, etc.

Township, Section, and Quarter Section Lines (*any one for township line alone, any two for township and section lines*)

Township and Section Corners Recovered

Boundary Monument

Triangulation Station

Bench mark BM 1232

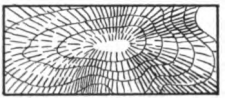
U. S. Mineral Monument

Fig. 8.—Conventional Signs.

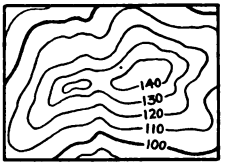
RELIEF

(Shown by contours, form lines, or shading as desired)

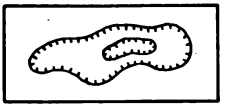
Hill Shapes



Contour System

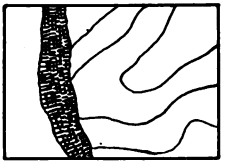


Depression Contours, if otherwise ambiguous, hachured thus

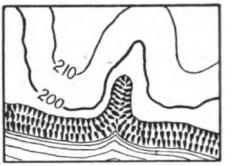


Bluffs

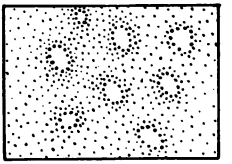
Rocky (or use contours)



Other than rocky (or use contours)



Sand Dunes



Levee

Fig. 9.—Conventional Signs.

LAND CLASSIFICATION

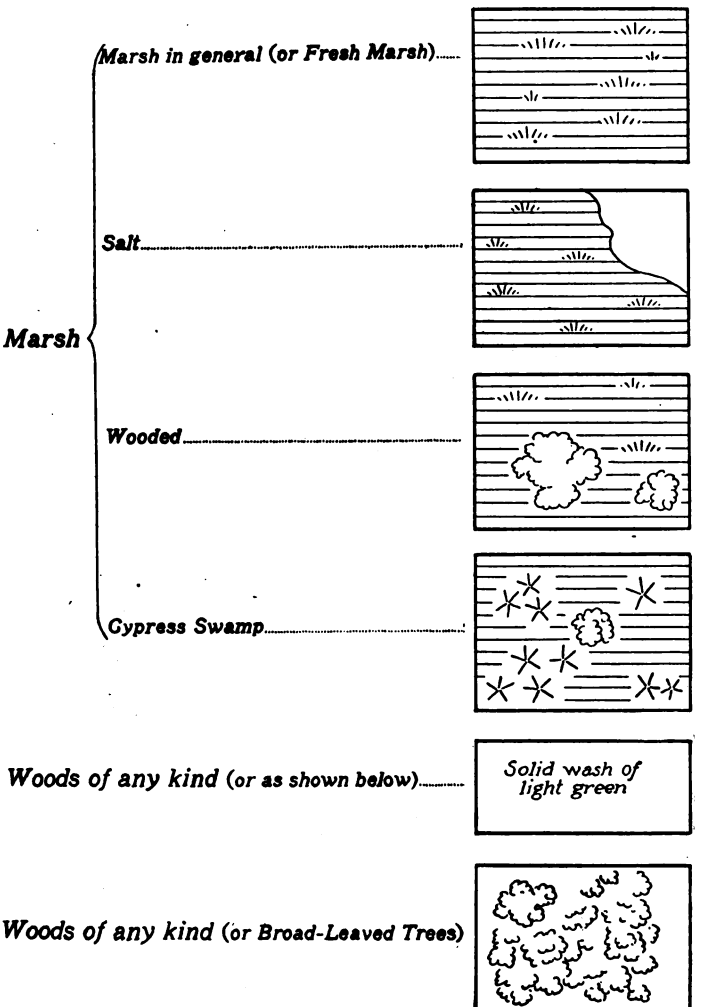


Fig. 10.—Conventional Signs.

LAND CLASSIFICATION

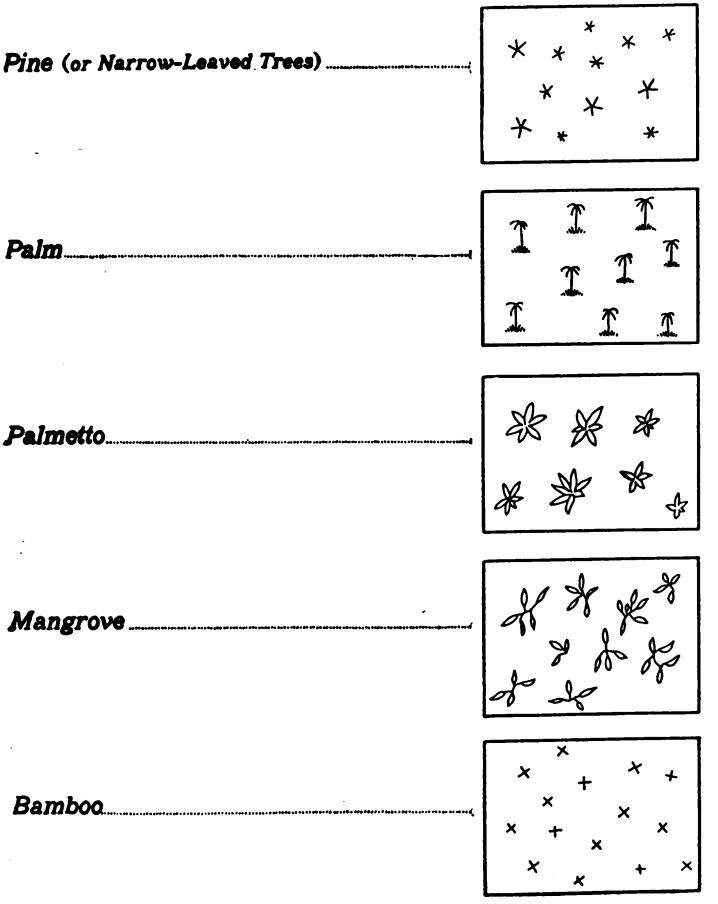


Fig. 11.—Conventional Signs.

LAND CLASSIFICATION

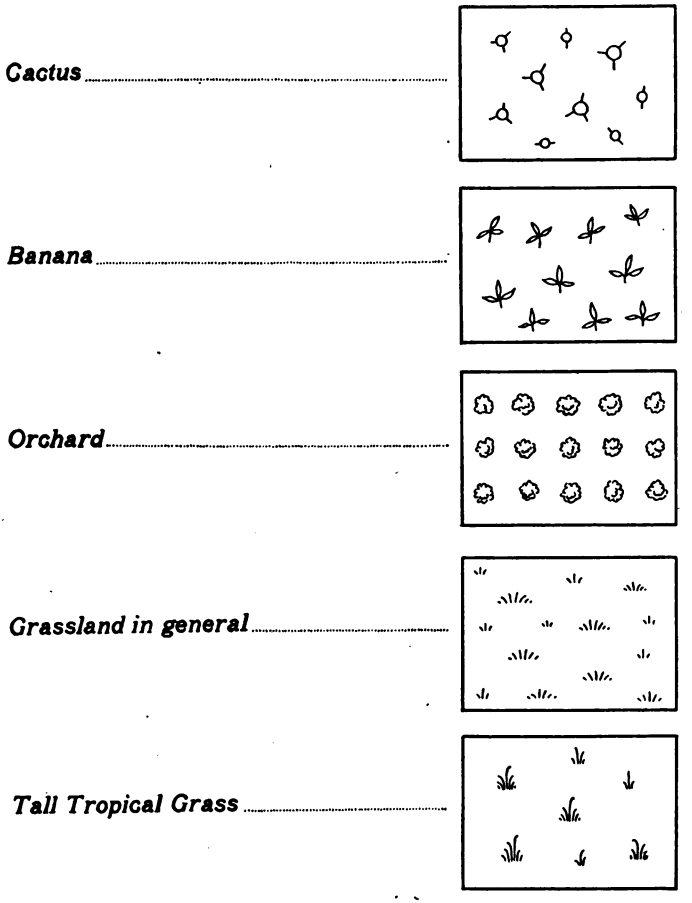


Fig. 12.—Conventional Signs.

LAND CLASSIFICATION

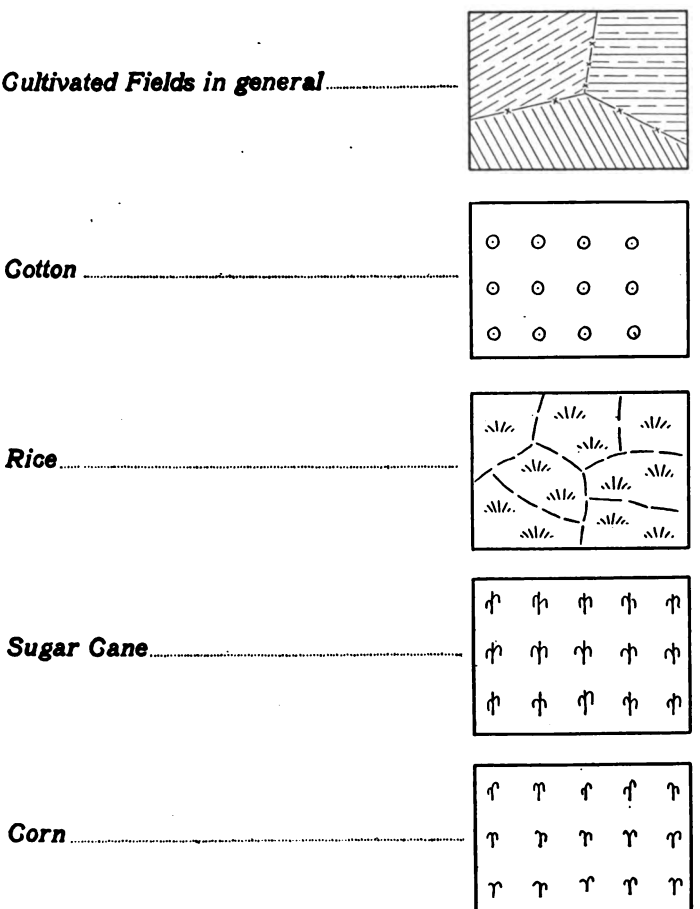


Fig. 13.—Conventional Signs.

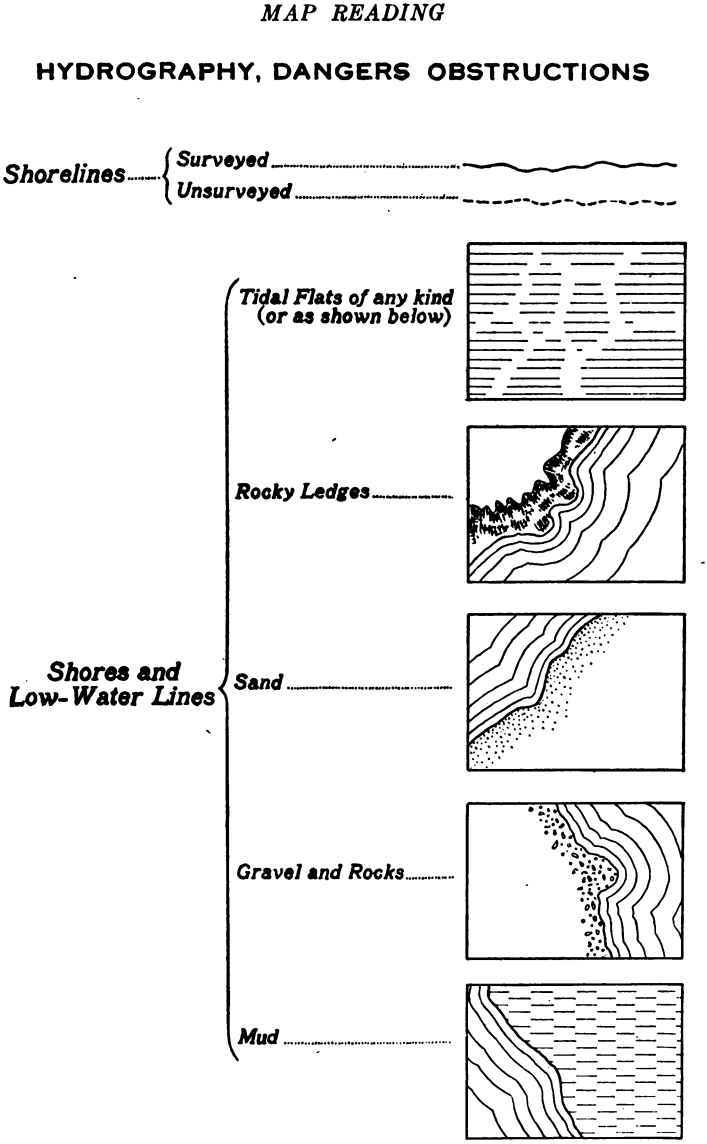


Fig. 14.—Conventional Signs.

DRAINAGE

Streams in general

Intermittent Streams

Lake or Pond in general
(*with or without tint, waterlining, etc.*)

Salt Pond (*broken shoreline if intermittent*)

Intermittent Lake or Pond

Spring

Fig. 15.—Conventional Signs.

CHAPTER VI

MAP READING—Continued

Representation in Relief

A map is of little value for military use unless it shows the form of the ground, since all military operations are affected by the character of the slopes, heights and positions of summits, etc. It is true that much may be inferred in regard to the general shape of the ground from the positions of the stream courses, especially if the general character of the country is known. But for military purposes it is necessary to have detailed knowledge of the ground forms, and the maps used must show them as accurately as possible.

Methods of Representing Ground Forms.

There are two general methods in use for representing ground forms:

1. By hachures; and
2. By contours.

Present practice has crystallized in the use of contours to the exclusion of the older method of representation by hachures.

Hachures

Hachuring has as its basis the representation of different slopes by means of shading strokes drawn in the direction in which water would flow on the ground at the point represented. The steepness of the slope is indicated by the length, weight, and spacing of the hachure lines. Gentle slopes are represented by long,

light strokes, comparatively widely spaced. Very steep slopes are represented by short heavy strokes, closely spaced. Suitable variations between these limits are used to represent intermediate degrees of slope. Level spaces are left blank.

For use in determining relative heights, the elevations above sea-level of points here and there on the map are given. These elevations are called "spot levels," and are stated in units corresponding to the scale of the map. Thus in metric maps, the elevations are always expressed in meters; in inches-to-miles maps, they are expressed in feet.

Fig. 16 shows an example of a hachured map with spot levels. It is a small section taken from one of the sheets of the $\frac{1}{80,000}$ General Staff map of France. It is of especial interest because of its use in the European War.

The defects of the method of representing slopes by hachures are: the absence of accurate representation; the very high degree of skill required to draw hachures acceptably; the time required to draw them; and the fact that on steep slopes the weight of the hachure shading almost precludes the representation of other information. The single counterbalancing advantage is that hachures give, in terms of light and shade, a sort of pictorial representation of the ground forms which is intelligible to an untrained eye and to the unimaginative mind.

Similar in principle to hachuring is the method of *stumping*, in which the desired shading is accomplished by rubbing pencil dust into the paper. It is then fixed by the application of water. Stumping requires much less skill and time than hachuring, but it is difficult to reproduce in maps.

CONTOURS

A contour is merely a line on the ground that marks all points of equal height above the mean level of the sea, or in other words simply a level line on the ground.

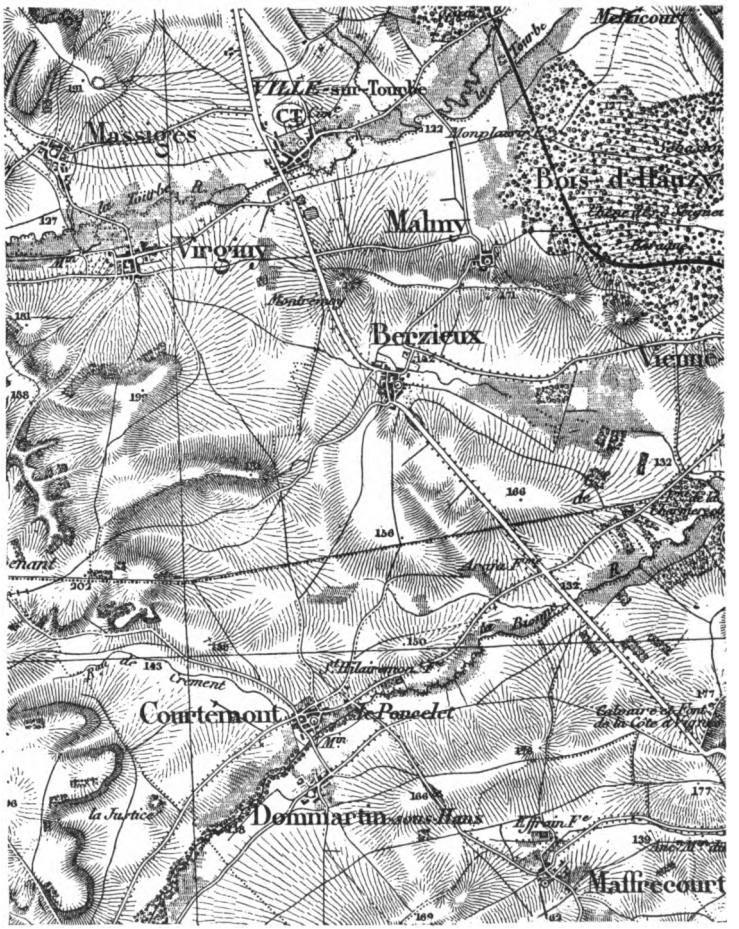


Fig. 16.—Hachured Map.

Contours on the Ground.

A physical conception of the line of a contour on the ground may be gained by setting stakes at intervals on the same level by the use of a hand level or engineer's level. A piece of irregular ground is preferable for this purpose, as it gives a much better illustration of the meanderings of a contour.

The illustration usually employed in books on topography to give a conception of contours on the ground is to conceive an island of irregular shape and with a variety of ground forms, and then to suppose that the water rises by successive equal stages. The shore lines at these various water levels would constitute a set of contours.

It is well to gain the conception of a contour on the ground as the location of a level path. This conception of a path can be followed out on any piece of ground. By conceiving a series of paths at equal differences of level, a set of contours results.

Contour Lines on the Map.

For purposes of representation on a map, all topographical features are considered as having been projected by vertical lines upon a horizontal plane beneath them, just as if the ground represented had sunk to a level and each object had moved directly downward to this new level. They are shown to scale on the map in this relation to each other.

For the purpose of representing contours on maps, the lines of the contours are considered to be similarly projected on a horizontal plane and drawn to scale in their proper positions relative to the other topographical features.

The lines on the map which represent the contours on the ground are also called contours. In the following discussion it will be necessary to distinguish between the contours on the ground and the contours on the map by continual repetition of these terms.

Datum Level.

For convenience, all elevations on topographical maps must refer to some datum, and the one regularly used is mean sea-level. The elevations shown upon maps resulting from formal surveys always represent vertical heights above mean sea-level. In small local surveys and for purposes of instruction, if the elevations above mean sea-level are not locally known, or cannot be referred to conveniently, the datum level may be assumed at some level below the lowest point in the area to be represented on the map. This is done by assuming the elevation of some point in the area to be 100 feet, or any convenient value, such that no point in the area will be below zero level. The elevations of the contours on the ground are marked upon the corresponding contours on the map.

Vertical Interval between Contours.

Although ground forms might be shown on a map by contours representing random differences of level, convenience requires that successive contours shall represent uniform differences of level. This difference of level between contours is called the *vertical interval*, abbreviated V.I.

The actual elevations represented by the contours are always expressed in meters on metric scale maps, and in feet on inches-to-miles maps. Although the V.I. may be 1 foot or 2 feet, or 1 meter or 2 meters for very large scale maps, the V.I. is usually 5 units or some multiple of 5. The usual contour intervals encountered in our units are 5, 10, 20, 50, and 100 feet, and in the metric units 1, 2, 5, 10, etc., meters.

The reason for the use of a uniform V.I. is that it is desirable that the contours on the map shall show the slopes as well as the form of the ground. With a uniform V.I., the map contours, which represent the horizontal projections of the ground contours, will be close together where the ground is steep, and far apart on gentle slopes. Thus the map spacing of the con-

tours will reflect accurately the slope of the ground. In fact, in rugged country, the contours give an effect of shading the steeper slopes similar to that of hachuring.

Methods of Stating Slopes.

For military purposes, it is customary to state slopes in degrees, but they may also be expressed as percentages, or as gradients. The degree of a slope is the angle in degrees which it makes with the horizontal. It is measured directly by the reading of the vertical circle of a transit, or by the reading of a clinometer.

The percentage of a slope is given by the number of units rise or fall in 100 units horizontal distance. Thus a 2 per cent slope means that there is a vertical rise or fall of 2 feet in 100 feet horizontal distance, or of 2 meters in 100 meters, etc.

The gradient of a slope is the ratio of the vertical rise or fall to the horizontal distance in which this change occurs, both expressed in the same units. Thus a rise or fall of 1 foot vertically in 12 feet horizontal distance may be called a slope of $\frac{1}{12}$, also referred to as a slope of 1 on 12.

Slopes are referred to as + or positive if the slope is upward from the point of observation, and − or negative if the slope is downward.

The degree, percentage, or gradient of a slope may be calculated from the contours on a map. The contour interval gives the rise or fall in the horizontal distance shown on the map between contours, and the ratio of these distances may be converted by calculation into degrees, percentage, or gradient.

Since each calculation would thus have to be made independently, it is much more convenient to construct a graphical scale for reading slopes.

Relation between Slope and Distance between Contours.

For the sake of convenience in constructing slope scales, it is assumed that the tangents of angles are directly proportional

to the angles themselves. This is not strictly true, but the error in the assumption is very small, as will be seen from the fact that the natural tangent of 1 degree is .01746, of 10 degrees is .17633, of 15 degrees is .26795, and of 20 degrees is .36397. From a comparison of these values, it will be seen that the error in the assumption increases with the degree of slope, but that it is still small even for 20 degrees, which is steeper than the slopes usually encountered in all but the most rugged country.

Under the assumption that the tangents are directly proportional to the slopes, it results that the distance between contours of equal intervals is inversely proportional to the slope

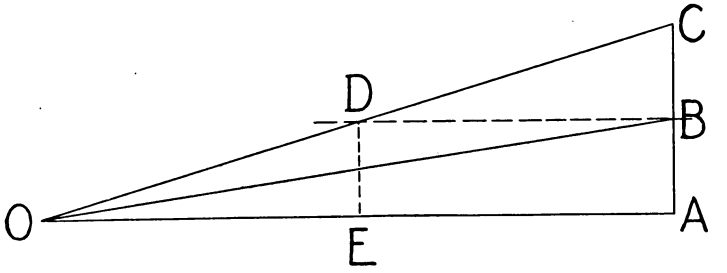


Fig. 17.—Map Distance between Contours.

represented. Thus the contours representing a 2-degree slope would be half as far apart as those representing a 1-degree slope, as will be seen by reference to Fig. 17.

In this figure the distance *AB* represents the vertical interval between contours, and the distance *OA* is the horizontal distance between them. If the distance *BC* be set off equal to the distance *AB*, the assumption that the slope in degrees of the line *OC* is double that of the line *OB* is very nearly true, and can properly be made with reference to lines no more accurately drawn than are contours, even on the best of maps.

From the figure it will be seen that the point *D* is at the same elevation as the point *B*, and that the distance *OE*, which

is the distance between contours on the slope *OC*, is one-half the distance between contours on the slope *OB*.

Under the same assumption that tangents are directly proportional to angles, a similar relation could be established in the case of slopes expressed in percentages or as gradients. Thus the contours are twice as far apart on a 5 per cent slope as on a 10 per cent slope, and twice as far apart on a $\frac{1}{20}$ slope as on a $\frac{1}{10}$ slope.

Relation between V.I. and Map Distance between Contours.

The actual horizontal distance between contours on a given slope is directly proportional to the V.I. Thus on a 5-degree slope, contours of 20 feet V.I. are twice as far apart as are contours of 10 feet V.I., and the map distance between contours bears, of course, the same relation. If, however, the 20-foot contours are drawn on a map-scale half as large as that on which the 10-foot contours are drawn, the map distances between contours representing the same slope will be the same on the two maps.

From the above, it is apparent that such a ratio may be maintained between the V.I., and the scale of the map that the same map distance between contours will always represent the same degree of slope. This is very satisfactory in theory, and would be very convenient in practice were it not for the fact that the V.I. must be selected with reference to the character of the country to be represented. Areas where the differences of elevations between summits and valleys are small require a small V.I. for adequate representation. On the other hand, in mountainous country the use of a small V.I. would result in such a number of contours that the map would be obscured by them.

The primary purpose of a map is to represent the ground. To do so, the V.I. must be selected to accord with the character of the country, and not to fit some theory based upon an easy and mechanical reading of slopes.

Construction of Slope Scales.

In the construction of slope scales, two factors enter:

1. The vertical interval between contours; and
2. The scale of the map.

A line having a slope of 1 degree rises 1 foot vertically in a horizontal distance of 57.3 feet, or 10 feet in 573 feet. Therefore the ground distance between contours of 10 feet V.I. on a slope of 1 degree is 573 feet. Under the assumption that tangents are directly proportional to the angles themselves, the ground distance between contours of 10 feet V.I. on any other degree of slope would be 573 feet divided by the degree of slope. Thus the ground distance on a 2-degree slope would be 286.5 feet; on a 3-degree slope, 191 feet; on a 5-degree slope 114.6 feet; and similarly for all other degrees of slope.

The ground distance between contours is directly proportional to the V.I. For a 5-foot V.I., the distance would be half those given above, for a 20-foot V.I. double the distances, and similarly for other intervals.

To construct a slope scale, it is only necessary to calculate the map distances corresponding to the V.I. and map scale desired, and then set off these distances on a line in some form convenient for use.

Two forms of slope scale are required:

(*a*) One showing the map distance for each degree of slope repeated only once, for use in measuring slopes on maps; and

(*b*) One showing the map distance for each slope repeated a number of times, for use in plotting contours in map making.

The two forms are shown to scale in the figures illustrating the examples following.

Example 1. Let it be required to construct a slope scale for use in reading slopes. Scale of map, 6 inches = 1 mile. V.I. = 10 feet.

Solution. The ground distance between contours for 1-degree slope for V.I. = 10 feet is 573 feet, and for all slopes the distance is inversely proportional to the degree of slope.

The R.F. corresponding to 6 inches = 1 mile is $\frac{6}{63,360}$ inch = $\frac{1}{10,560}$. 573 feet = 6,876 inches. The map distance corresponding to 573 feet is $\frac{6876}{10,560} = .651$ inch, which is the map distance between contours of 10-feet V.I. on a 1-degree slope. For a 2-degree slope, the map distance is $\frac{.651}{2} = .325$ inch; for 3 degrees, $\frac{.651}{3} = .217$ inch; etc. Set off the calculated lengths of the map distances corresponding to the various degrees of slope successively on a line, and mark the divisions with the corresponding slopes, as shown in Fig. 18. This scale is applied to the map to determine the scale division most nearly equal to the perpendicular distance between contours, and the slope of the ground is given by the marking of the division.

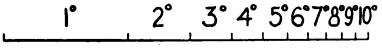


Fig. 18.—Slope Scale for Map Reading.

Example 2. Let it be required to construct a slope scale for plotting contour intervals. Scale of map $\frac{1}{10,000}$. V.I. = 5. meters.

Solution. The V.I. being 5 meters, the map distance between contours on a 1-degree slope will be $57.3 \times 5 = 286.5$ meters. It is to be noted that in the metric system, the map distance could be taken directly from the reading scale of kilometers. To construct the slope scale from a scale of inches, it is necessary to reduce to our units. The distance 286.5 meters reduced to inches is $286.5 \times 39.37 = 11,279.5$ inches. The map distance corresponding to this ground distance is $\frac{11,279.5}{10,000} = 1.128$ inches. Corresponding fractional parts of this distance give the map distances for the other degrees of slope.

Since it is desired to repeat each contour interval a number of times on the scale, it is best to construct five separate scales, having as the smallest divisions 12, 10, 9, 8 and 7 degrees respectively. Two divisions on each scale will represent the map distance between contours for one-half the degree of slope. Hence, by suitable marking the 12-degree scale will answer for 12, 6, 3, and $1\frac{1}{2}$ degrees; the 10-degree scale for 10, 5, and $2\frac{1}{2}$ degrees; the 9-degree scale for 9 and $4\frac{1}{2}$ degrees; the 8-degree scale for 8, 4, 2, 1, and $\frac{1}{2}$ degrees; and the 7-degree scale for 7 and $3\frac{1}{2}$ degrees. These five scales cover all slopes up to 5 degrees by intervals of $\frac{1}{2}$ degree, and from 5 up to 12 degrees by intervals of 1 degree (except 11 degrees). These scales are shown in Fig. 19. They are printed on the

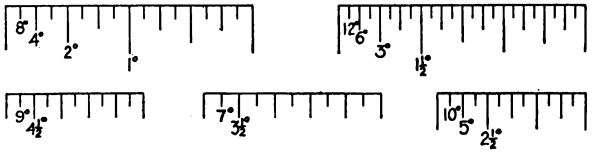


Fig. 19.—Slope Scale for Map Making.

sketching board and also on the edges of the alidade of the standard sketching equipment in use by the United States Army.

Scales of this form may also be used for reading slopes on maps, but they are not nearly as convenient for this purpose as the form shown in Fig. 18.

It is to be noted that a slope scale can be used for different map scales and vertical intervals than those for which it was constructed, provided the new scale and V.I. have certain relations to the old. Thus a slope scale for a map of scale 6 inches = 1 mile and V. I. = 10 feet may also be used for the same map scale and V. I. = 5 feet by halving all the intervals; for a map scale 3 inches = 1 mile and V.I. = 20 feet without change; or for a scale of 3 inches = 1 mile and V.I. = 10 feet by halving the intervals.

The use of slope scales in map making will be discussed in a later chapter under the subject of topographical sketching.

Problem 1. Construct a slope scale for use with map of scale $\frac{1}{20.000}$ and V. I. = 5 meters.

Problem 2. Construct a slope scale for use with the United States Geological Survey maps, scale $\frac{1}{62.500}$, V. I. = 50 feet.

Problem 3. Construct a slope scale for use with Plate A, scale $\frac{1}{10.560}$. V. I. = 10 feet. Upon Plate A, identify slopes of 1, 2, and 3 degrees.

CHAPTER VII

MAP READING—Continued

CONTOURS—CONTINUED

Forms of Contours.

ALTHOUGH the forms of contours can be studied much better on the ground, a certain familiarity with the subject can be acquired by indoor study, illustrated by clay or plaster models or by the sand box.

It is desirable to revert to the conception of a contour as a level path upon the ground, and to consider the process of following a contour on the ground as that of selecting the location of such a level path.

Valley Contours. Let us consider ourselves as being upon the sloping side of a narrow valley, and carry out in imagination this process of following a contour up the valley. The surface of the stream itself rises toward its source, therefore there will be some point on it which is at the same level as the assumed starting point. If we start up the valley, keeping on a level path, we will gradually come nearer the stream and actually reach it at the point level with the starting point. After crossing the stream we must turn sharply down and follow on the opposite side of the valley a course similar to that followed in going up-stream, gradually getting farther from the stream as we proceed. The course followed marks a contour and its map representation would be of the form shown in (*a*), Fig. 20. The arrowhead indicates the direction in which the stream flows.

If a small tributary stream had been encountered before the contour crossed the main stream, the contour would have turned up the valley of the tributary, crossed it and returned on the other side to the main valley, when it would again have turned up the main valley as before. The resulting contour form is that shown in (*b*), Fig. 20. Additional tributaries would have resulted in the contour taking the general forms shown in (*c*) and (*d*), Fig. 20.

The forms of contours shown should be remembered as typical forms of valley contours. The width of the opening of the V of the contours as compared with the total distance up-stream to the point of the V will vary with the characteristics of the

Fig. 20.—Typical Valley Contours.

valley. Thus in a narrow valley with steep sides and no level bottom, the V of the contours will be long and narrow, whereas in a wide valley with gentle slopes, the V shape will be usually more open. The actual forms for these different cases should be studied and drawn on the ground. It will always be a surprise to the beginner in topographical mapping to find how far up-stream the loops of the valley contours extend.

If the tributary valleys had been small in extent, insufficient to collect enough water to form a running stream, the presence of these small tributary valleys would have been indicated by the form of contours shown in Fig. 21.

Spur and Ridge Contours. If we consider the spurs and ridges between tributaries of the same stream, some of them will be found to be narrow and sharp, marked by a narrow U-shaped

form of contour, as shown in (*a*), Fig. 22. Varying degrees of the sharpness of the ridges will be marked by different forms of the U-shaped contours, as shown in (*b*) and (*c*), Fig. 22. The forms of these spurs and ridges are determined by erosion, and they reflect the plan of the streams which have carried out this

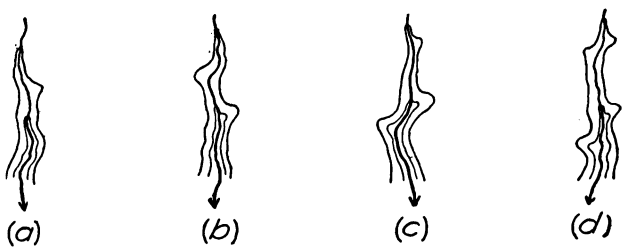


Fig. 21.—Dry Tributary Valleys.

work. In illustrating these typical forms of contours, the student is reminded that they are to serve him only temporarily until he is prepared to work them out for himself on the ground.

Summit Contours. Turning now to the high ground, there will be found along the ridges between the branches of the streams,

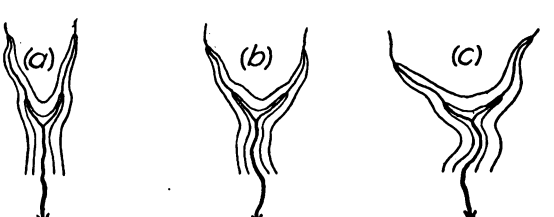


Fig. 22.—Spur and Ridge Contours.

and particularly along the main ridges separating the headwaters of different streams, occasional hills higher than any of the surrounding ground. A contour traced near the summit of such a hill would not wander off indefinitely into the surrounding

country, but would pass completely around the summit of the hill and close upon itself. If the summit of the hill were round, the contour would be circular in form; if oblong, the contour would be oval; and in nature such summits will be found in an infinite variety of forms, with corresponding variety in the shapes of the contours representing them.

As we go downward from the summit, the contours show the irregular beginnings that develop into the ridges, spurs, and valleys of the lower ground.

Col or Saddle Contours. One ground form which should be mentioned and studied is the col or saddle. This form usually results when a ridge separating two streams is indented by nearly opposite tributaries of the two streams, also in similar cases along the ridge forming the high ground or watershed separating two different drainage basins. The latter form is usually called a *gap.*

In this type form we have the situation shown in (*a*), Fig. 23, where the point marked X is a low point on the ridge line. From X it would be necessary to go up hill to get to the top

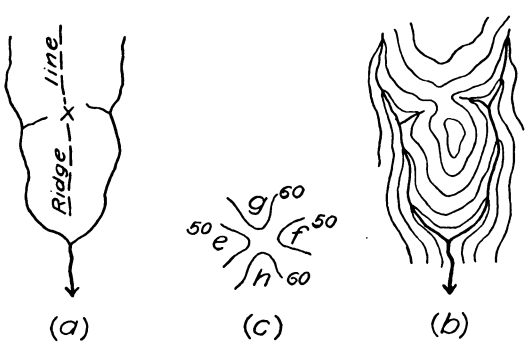


Fig. 23.—Col or Saddle.

of the ridge in either direction, whereas the ground would fall toward the stream on each side. The map contours representing

the col or saddle are shown in (*b*), Fig. 23. In this form the highest pair of valley contours, *e* and *f*, in (*c*), Fig. 23, are always a contour interval lower than the lowest pair of ridge contours, *g* and *h*.

Representation of Slopes by Contours.

Contours show by their trace the form of the ground, and by their spacing not only the declivity but also the character of the slopes. The latter is very important from a military standpoint.

Uniform Slopes. From any point on a uniform slope the whole of the slope can be seen, and the slope can be swept either up or down by a grazing fire.

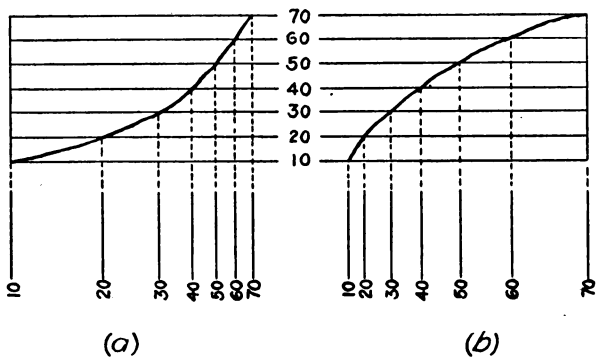


Fig. 24.—Concave and Convex Slopes.

A uniform slope is indicated by a uniform spacing of contours,—steep slopes by close and gentle slopes by wide spacing.

Concave Slopes. A concave slope is one which grows steeper as it rises. From any point on such a slope the whole of the slope can be seen, but fire aimed at any point on the slope will pass too high above the other portions of the slope to be effective.

The contours representing a concave slope diminish in spacing toward the top of the slope as shown in (*a*), Fig. 24.

Convex Slopes. A convex slope grows more gentle as it rises. From any point on a convex slope the view and field of fire are limited.

The contours representing a convex slope increase in spacing toward the top of the slope, as shown in (*b*), Fig. 24.

Exercise 1. That portion of Plate A lying north of the road past the waterworks should now be examined to identify valley, spur, summit, and saddle forms, also uniform, convex, and concave slopes.

Exercise 2. There is an error in numbering one of the contours in Plate A. Find the error and correct it.

Plate A is a map of an area of comparatively small differences of elevation and gentle slopes. Any other maps available should be examined to identify the ground forms mentioned.

Models and Sand Box.

In gaining a conception of the type ground forms, models made of plaster of Paris or of some of the market preparations of modeller's clay, or the sand box may be used. The models of plaster or clay may be worked out as careful reproductions of the ground as represented by a map. The contours may be marked upon the models, and in a general way they will be found of assistance in aiding the student's conception of the contoured representation of ground forms.

Of practically equal service is the shallow box of moist sand, and this can be made available for any class at trifling cost. The moist sand is modelled into forms for illustration, and the contours can be indicated by lines marked on the sand. Ground forms may be modelled in the sand box to be used as the basis of contoured representation on a reduced scale.

The difficulties with the use of models or the sand box for instruction in topography are that in them the vertical scale

must be greatly exaggerated, and that the models reproduce the map and not the ground from which the map was made. The models, therefore, give no conception of the errors and generalizations of the map itself as a representation of the ground, nor do they give any conception of the difficulties that confront the topographer on the ground.

The reason for using an exaggerated vertical scale in constructing models of ground forms may be seen by assuming that Plate A is to be reproduced as a relief model. The scale of this plate is 6 inches = 1 mile, so it would be reproduced in full size as a plan of the area. The total difference of elevation or relief is 150 feet. The map distance corresponding to 150 feet on a scale of $\frac{1}{10,560}$ is $\frac{150 \times 12}{10,560} = .17$ of an inch. In other words, if a relief model the size of Plate A were constructed to show this ground, the total vertical height necessary to show the relief to scale is less than $\frac{1}{5}$ of an inch. Yet the ground itself would give the impression of being much rougher than would the scale model. To overcome this difficulty, it is customary to exaggerate the vertical scale of the model to 5 or 10 times the horizontal scale.

This exaggeration of the vertical scale is necessary, but the difficulties of model representations must be borne in mind in order to avoid false conceptions.

Contour Problems.

Further familiarity with the type forms of contours can be gained by drawing the contours of an area, having given the stream courses and the elevation of points where the slope of the ground changes. This class of problems will be taken up in connection with the subject of topographical sketching in Chapter XI.

Construction of Profiles.

Problems in the construction of profiles along lines drawn on a map give excellent practice in gaining familiarity with the interpretation of contours. The same objection as in models will,

however, be encountered with respect to the necessary exaggeration of the vertical scale.

Profile or cross-section paper is convenient for the construction of profiles, but if not at hand plain paper can be used, or the profile can be constructed directly on the map itself.

To construct a profile, select on the map the line of which the profile is to be drawn. This line may be either straight or meandering. Select a line of the profile or cross-section paper to represent datum level, or draw such a line on the plain paper. On the edge of a piece of paper take off from the map all points along the profile line where contours and streams cross it, and transfer these points to the line on the paper on which the profile is to be drawn. On perpendiculars at these points set off, to the vertical scale selected, distances corresponding to the heights represented by the contours, and mark also the positions of the crests and stream crossings. Connect these points by a continuous line without any abrupt breaks. This line will represent a profile of the ground along the line selected, as shown in Fig. 25.

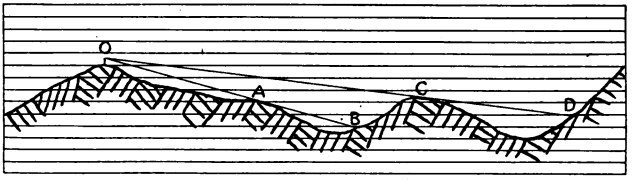


Fig. 25.—Visibility of Points and Areas.

The high points where the profile line crosses the crests of spurs or ridges and the low points where it crosses the streams will have to be determined in elevation by estimation, using the theory that the slope is uniform between contours. Let us assume that a profile is to be constructed on the 16-minute line of Plate A. Just north of the waterworks road the profile line crosses the spur between Indian Creek and its tributary. At the highest point

of the profile line just west of the oval 100-foot summit contour, the profile line gains about .6 of the interval between the 70 and 80-foot contours. The highest point of the profile line is therefore 76 feet where it approaches nearest the 80-foot contour. Just south of this road, the profile line crosses the tributary of Indian Creek. The level at the tributary would have to be determined by first determining the height of Indian Creek at the bridge, which is about $\frac{1}{10}$ of the distance between the crossing of the 40-foot contour northwest of the bridge, and the crossing of the 50-foot contour southeast of the bridge at the edge of the woods. The elevation of Indian Creek at the bridge is therefore 41 feet. The profile line crosses the tributary about $\frac{1}{4}$ of the distance between the bridge and the 50-foot contour crossing, or at an elevation of about $43\frac{1}{4}$ feet.

Problem 1. Construct a profile along the pipe line from the corner of the waterworks to the reservoir. Plate A.

Problem 2. Construct a profile of the road from Red River to the reservoir. Plate A. (Note.—The fraction written at the bridge over Indian Creek, $\frac{190 \times 15}{20}$, means that the roadway of the bridge is 190 feet long and 15 feet wide, and that the roadway is 20 feet above the level of the water.)

Problem 3. Is the data for the bridge near the northeast corner of Plate A correct?

Visibility.

Another excellent exercise for gaining familiarity with the interpretation of contours and slopes is the problem of determining whether one point is or is not visible from another point on the map.

It is necessary to warn the student that, due to the inherent inaccuracy of contour representation, the evidence drawn from the map with regard to the visibility of points is not absolutely conclusive concerning the actual visibility or otherwise of the points on the ground, but this does not detract from the value of

visibility problems as an exercise in the interpretation of contours on the map.

It will be seen from an examination of the profile drawn under Problem 1 above that the profile will serve to show whether any ground form along the line shuts out the view between two selected points on the profile. This is true notwithstanding the exaggeration of the vertical scale, because the slope of the line representing the visual ray is exaggerated in the same proportion as all other vertical dimensions. If a straight line drawn between two points on the profile lies above all intermediate points of the profile, then each point is visible from the other.

The point of view may not be the surface of the ground, but may be the height of the eye of an observer standing, or the observer may be in a tree or other elevated observation point such as a tower or captive balloon. In these cases the height of the observation point above the point in the profile must be determined and plotted.

If in a profile a line be drawn from any observation point tangent to a hill, the point of tangency will show the limit of visible points on the hill itself, and the line of sight prolonged will show how much of the succeeding valley is screened from view and how much of the surface lying beyond can be seen. This is illustrated in Fig. 25 in which O is the point of observation. All ground is visible to the point A, where the ground dips and cannot be seen until the point B is reached. The ground from B to C is visible, but all ground from C to D is concealed by the hill C. These points A, B, C, and D can be transferred from the profile to the map. Successive profiles radiating from O will serve to determine a succession of points A, which when joined on the map will form a line of screen, and with points B will serve to outline an area invisible from O. Similarly, the invisible area of which C D is a part can be determined.

It is not necessary to construct the full profile in order to solve problems of visibility. The elevation of the point of obser-

vation is given by the conditions of the problem. An examination of the ground forms and of the spacing of the contours will serve to disclose the probable points of screen. A construction of the profile at these points may be necessary to determine the exact location and elevation of the screening point. Having established the elevation of two points on the line of sight, the elevations corresponding to contours can be marked off on it, and these elevations compared with the elevations shown on the contours on the map. So long as the elevations along the line of sight are greater than the elevations of the contours of the ground, the ground is invisible. When a point is reached where the opposite is true, the ground becomes visible. The point where the line of sight strikes the surface can usually be determined approximately by inspection. Since the solution is not exact anyhow, no great degree of precision is necessary in determining where the line of sight strikes the ground.

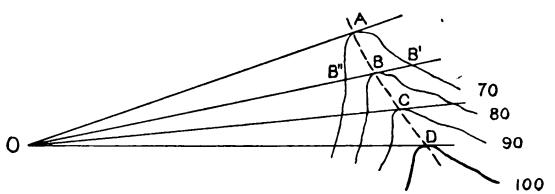


Fig. 26.—Line of Screen on Spur.

In determining the line of screen on a spur, it may only be necessary to draw from the observation point lines tangent to the contours of the spur, and then connect the points of tangency, as in Fig. 26. To permit the use of this method, the observation point must be neither too close to, nor much higher or lower than the spur, otherwise the solution may not be true.

Thus in Fig. 26, if the line *OB*, tangent to the 80-foot contour, be regarded as a profile line, the point *B* will be the highest point in this profile and hence the screening point, unless the

point O be either close to and higher than B, in which case the point B' may be visible, or if the point O be close to and much lower than B, the point B'' may screen the point B from view. In either of these cases it is only necessary to compare the slope of the line OB with either that of BB' or BB''.

When models of the ground are available, the solution of visibility problems is simplified by the use of a small flash-light. This light is placed at the location of the observation point, and such areas of the model as are in shadow are screened from view from the observation point.

The question of visibility may be solved from either our own point of view to determine the points within the enemy lines which are hidden from our view, or from the enemy point of view to ascertain the areas wherein our own movements and works are hidden from him. Of particular importance are questions of the points visible from the captive balloons, which are now much used for observation purposes.

Visibility Problems.

Visibility problems fall into five general classes:

(*a*) Is the point A visible from the point B? Solve for visibility as already explained.

(*b*) How high would an observation tower (or captive balloon) at the point A have to be in order to see the point B?
From the point B find the screening point in the direction of A. From the height of B and of the screening point, find the elevation of the line of sight from B at A. The difference between this elevation and that of the ground at A is the required height of the observation point.

(*c*) How high above ground would an observation balloon have to be at the point A in order to see all of the ground within a specified area?
Examine the specified area to find the steepest slope (i.e., closest contour spacing) facing away from A. The contour

spacing must be measured along lines radiating from *A*. This contour spacing and the V.I. of the map determine the maximum slope the line of sight from *A* must have in order to see all of the area. From these data find the height of the point of sight at *A*.

If the area is large, several slopes may have to be investigated, because a slightly smaller slope at the farther edge of the area might require a higher observation point. In this case use the highest elevation determined.

If the height of the observation point above the ground is required, subtract the elevation of the ground at *A*.

(*d*) What areas within certain limits are not visible from the point *A*? Solve as already explained for visibility of areas.

(*e*) Observation balloons observe regularly from an altitude of 5,000 feet above datum at the points *A* and *B*. Is there any point near *C* where a building 30 feet high can be built which cannot be seen from either of the observation balloons?

Find the screened areas near *C* for each of the balloons independently. Investigate the points where these screened areas overlap.

Problem 1. Plate A. Are the waterworks visible from the 100-foot hill east of 16 minutes on the southern border of the map?

Problem 2. Plate A. How high would a flag pole at the Marion Junction station have to be to be seen from the belfry of the church in Weston, 30 feet above the ground?

Problem 3. Plate A. How high would an observation balloon at Marion Junction have to be to see all of the area included between the waterworks and reservoir roads?

Problem 4. Plate A. What parts of the road east from the waterworks are visible to a man standing on top of the 100-foot hill south of the reservoir?

Problem 5. Using any map available, solve a problem similar to (*e*) above. The area shown by Plate A is insufficient for such a problem.

Although visibility problems are valuable exercises in the study of contours on a map, it is well to caution the student once more against placing too much confidence in the results of the solutions of these problems as applied to the ground. Inaccuracies in map locations, inaccuracies in the contours, and the screening effect of trees and other vegetation introduce factors of uncertain effect.

Problem 1 may be solved in good faith, but in practice there is tall tropical grass on the 100-foot hill and bamboo on the screening point. In Problem 3 a little error of the topographer or a little slip of the draughtsman's pen would affect the answer by several hundred feet. The true test of visibility is on the ground itself.

CHAPTER VIII

MAP READING—Continued

Map Reference

Designation of Points on Maps.

In the problems at the end of Chapter VII it was necessary to identify points on Plate A by descriptions of considerable length. Thus one point was referred to as " the 100-foot hill east of 16 minutes on the southern border of the map." For random points on the map, it is impossible to frame a description which will identify them accurately.

In the military use of maps, it is essential to be able to identify unmistakably, and to describe briefly and accurately in an order or message, *any* point on any map to which it is desired to refer.

Map Sheets.

General topographical maps issued in time of peace usually consist of a series of practically rectangular sheets, all on the same scale. Areas of especial importance may be issued on larger scales. These map sheets are usually identified by the name of the principal town within the limits of the sheet.

If the military forces have occasion to prepare their own maps, the varied uses for which they are intended will require that maps of several different scales be issued. Thus there may be a general map on a scale of $\frac{1}{40,000}$ with issues of special areas on $\frac{1}{20,000}$, $\frac{1}{10,000}$, etc. If the successive scales of the map sheets are in this proportion, then four sheets of the $\frac{1}{20,000}$ map may be made to cover the same limits as one sheet of the

$\frac{1}{40,000}$, four sheets of the $\frac{1}{10,000}$ the same limit as one sheet of the $\frac{1}{20,000}$, etc., and all map sheets will be of the same actual size.

Map Reference.

For military purposes, it is necessary to identify a point as being on a particular sheet of a given series of maps, and then as being at a particular point on that particular sheet. *Map reference* is the term applied to the system by which this is accomplished.

Different systems of map reference are in use. It is not desirable to describe any of them in full detail, because the explanation would be complicated, and any system of map reference can be learned in a short time with maps exemplifying the system at hand. It will suffice here to describe the general principles governing them all.

Reference Lines. It is first necessary to assume a set of coordinate axes to which all points on every sheet of the whole series of maps can be referred. Reference lines parallel to the coordinate axes and at convenient intervals, such as 1,000 yards or 1,000 meters, are overprinted on all map sheets of the whole series. Such a set of reference lines is termed a *grid,* and divides the map sheets into squares.

In order to prevent confusion, it is desirable that the grid shall be continuous for the entire system of maps, that the map sheets shall be square or rectangular in form, and that the boundary lines of all map sheets shall correspond to lines of the grid system.

For purposes of map reference, the grid may be used in two different ways: (*a*) the grid lines may be numbered consecutively from some origin and all points given by coordinates from the origin; or (*b*) the map sheets may be laid out to correspond to lines of the grid and points on each map sheet designated by their coordinates on that sheet.

The first system, which may be called the *coordinate system,*

is very simple in its application. All sheets of whatever scale have the grid overprinted with each line bearing its number from the origin. The points are designated by their coordinates from the origin and may be found readily on any map of any scale.

The second system, which may be called the *sheet system*, requires that the reference system shall be worked out on the sheets of some selected scale, and a suitable reference grid overprinted on the map sheets of this scale. The larger scale subdivisions of these standard sheets must each bear its corresponding part of the grid carrying the same designations as on the standard sheet, in order that the same point may have the same reference designation on the map sheets of different scales. This system requires special means for identifying the map sheets of the various scales.

Designation of Map Sheets. The sheets of the general map may be either numbered or named. The name usually assigned to a sheet is that of the principal town on the sheet. Numbers are assigned serially in some regular order. The numbers or names of the general map sheets are usually shown on a key map.

We may assume that one of the general map sheets, scale $\frac{1}{40,000}$, has been designated as sheet 12. The four corresponding sheets of the $\frac{1}{20,000}$ map may then be designated 12 NE, 12 SE, 12 SW, and 12 NW. The four $\frac{1}{10,000}$ sheets corresponding to 12 NW may be designated 12 NWa, 12 NWb, 12 NWc, and 12 NWd. If the area shown by sheet 12 NWd is to be represented on a scale of $\frac{1}{5,000}$, the four sheets can be designated 12 NWd1, 12 NWd2, 12 NWd3, 12 NWd4. All sheets covering portions of sheet 12 are thus identified with it by their designations.

Sheet System of Reference. Upon whatever large-scale subdivisions of sheet 12 a point may be shown, the reference number for it must be the same. This is accomplished by subdividing sheet 12 into a number of lettered squares, as *A*, *B*, etc. These

lettered squares are then subdivided into numbered squares, as *A*1, *A*2, etc. Squares of this designation should be 1,000 yards or 1,000 meters on a side. They may again be subdivided into four squares each 500 meters or yards on a side, designated by additional small letters, as *A*5*a*, *A*5*b*, *A*5*c*, and *A*5*d*.

The large-scale subdivisions of sheet 12 must show the appropriate portion of this grid with its squares properly designated, so that the square designated *M*25*d* on sheet 12 shall be possible of identification as the same square on the $\frac{1}{20.000}$, $\frac{1}{10.000}$, etc., sheets which show it. The general scheme of such a system is shown in Fig. 27.

Location of Points in Grid Squares. The means by which the grid squares are identified have been pointed out. Points in the grid squares are located by their coordinates in the square, as shown in Fig. 28. Suppose the figure to represent grid square *A*6 of sheet 12, this square being 1,000 yards on a side. The lines representing the subdivisions into the *a*, *b*, *c*, and *d* squares may be shown broken, the subdivisions into tenths on the sides of these squares indicated by marks, giving the necessary means of subdividing into squares, as shown in square 6*a*. The coordinates of any point in square 6*a* may be given by its distance from the lower left (or right) hand corner of the square, first the horizontal distance and then the vertical, as 6*a*87 for the small circle marked. For more accurate identification the coordinates in the small square may be estimated, as 6*a*2218 for the point within the small circle. In this case the 22 is the horizontal coordinate, and 18 the vertical coordinate. In this system the sheet coordinate designation must be added to the sheet number, and the full description of the last point is 12*A*6*a*2218.

In the continuous coordinate system, the coordinates of a point in the grid square are merely added to the coordinates of the corner of the square, thus giving the coordinates of the point from the origin.

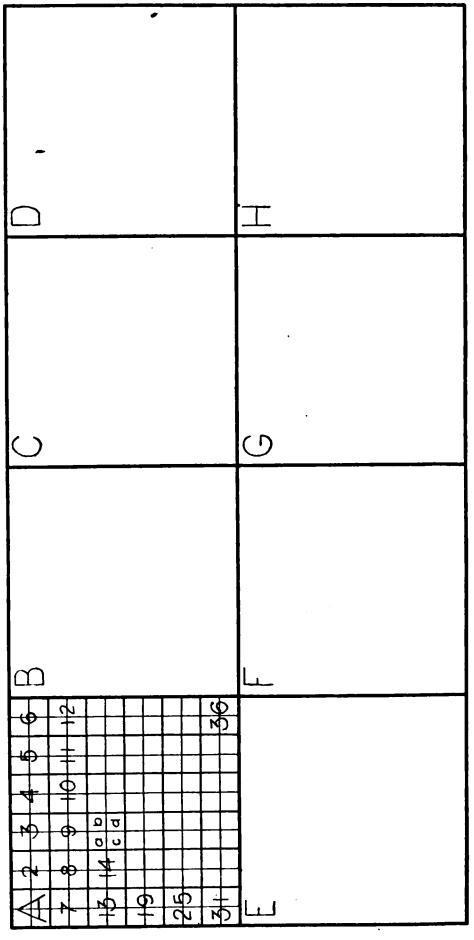


Fig. 27.—Sheet System of Map Reference.

For the purpose of measuring the coordinates of a point in the grid square, a scale may be made on two edges of a card, though a preferable form is one scratched on thin celluloid.

The above description is far from complete, in that the rela-

tion of map reference to map projection has barely been mentioned, whereas the two subjects are intimately related.

There is one point in this connection, however, which must be mentioned. The grid lines printed on a map are parallel to each other, whereas on any map projection fit for military use the lines of latitude are curves, and the longitude lines or true

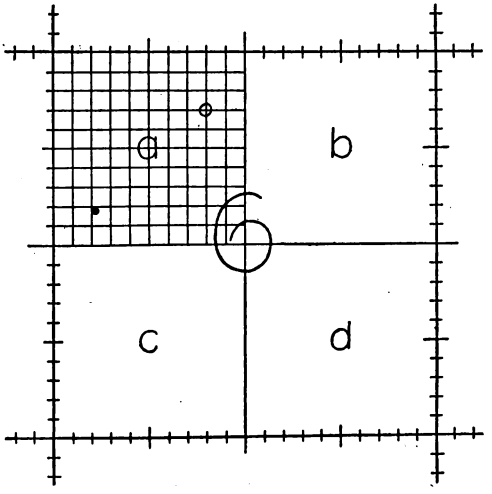


Fig. 28.—Location of Points in Grid Squares.

meridians are converging. Hence it is that as we recede from the origin of any grid system, its lines depart more and more from the meridians of the map. This leads to the use of the term "grid north," which is the direction of the grid lines, differing from the magnetic north shown by the needle and the true north shown by the direction of the projection lines of the map. The angle between grid north and the meridians of the map, called the *gisement* of the grid, is one of frequent use in working with maps showing map reference grids.

CHAPTER IX

MAP READING—Continued

Directions and Positions on Maps

ORIENTATION

Direction.

The standard direction is the true north. The direction of any line is the horizontal angle which it makes with the standard direction.

Determination of Direction.

The Magnetic Needle. The only instrument readily available at all times for the determination of direction is the magnetic needle or compass. The needle is subject to certain minor variations, and may be locally disturbed by the presence of magnetic bodies, but in any one locality and for any given year, the magnetic needle may be said to point always in the same direction.

The direction indicated by the needle differs in different localities, and in the same locality this direction is subject to slow but regular changes. The angle between the true north and the magnetic north is called the *magnetic declination.*

In order to refer to the true north directions determined by the needle, it is necessary to know the magnetic declination for the locality and the time in question. This is usually known locally or is a matter of easily accessible record. If not, the true north must be determined by observation, from which the local magnetic declination can be determined.

Accurate observations for true north must be made by the transit, by methods described in text-books on surveying and not necessary to repeat here. It is convenient, however, to be able to determine the true north approximately by Polaris, and roughly by the Sun.

Approximate North by Polaris. Polaris is a star whose angular distance from the true pole is about 1° 18′. It can be readily identified by the " pointers " in the Big Dipper, and should be remembered in its relation to the pole, the Big Dipper, and the constellation Cassiopeia, as shown in Fig. 29. Note that the true pole is on the line with Polaris and the two stars

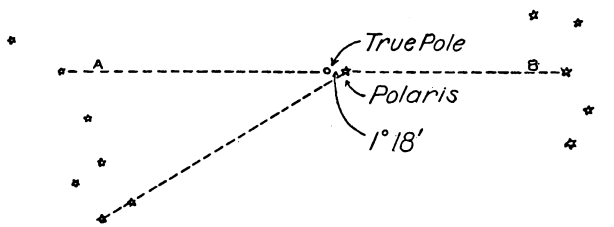


Fig. 29.—Approximate North by Polaris.

indicated. When this line is vertical, Polaris is on the meridian or true north. When the line is horizontal, the azimuth or direction of Polaris is approximately 1° 30′ at latitude 40 degrees, increasing about 1 minute for each degree increase of latitude.

The direction of Polaris can be established by suspending a plumb line from a height of about 8 feet, and arranging a sighting point a few feet in rear. If the observation is made when the line *AB*, Fig. 29, is vertical, the line established is the true north; if horizontal, the line established will be 1° 30′ from the true north on the side away from the Big Dipper. If the line established be prolonged and read by the compass, the magnetic declination will become known approximately.

Approximate North by the Sun. With a watch lying flat, point the hour hand in the direction of the sun, using a match or pin held in a vertical position to cast a shadow if necessary to get the correct direction. Half-way between the hour hand and the XII mark will be the south point. This method is inapplicable in low latitudes where the sun is nearly overhead. A second method is to mark at about 9:00 A.M., the point where the top of a vertical pole casts a shadow. Describe a circle on the ground with the vertical pole as a center and the distance to the marked point as a radius. Watch for the shadow of the top of the pole to cross the circle in the afternoon, and mark the point where it crosses. Bisect the line joining these two points, and the point so determined will, with the base of the pole, mark a north and south line. This method really determines roughly when the sun is at equal altitudes morning and afternoon. Half-way between, it was on the meridian.

Orientation.

Orientation is the process of determining direction. Orienting a map means setting it in such a position that the north lines of the map point to the true north. Then all lines on the map are parallel to the corresponding lines on the ground.

Orientation of a map may be accomplished by (*a*) setting the north line of the map in its correct direction by compass, or (*b*) by setting the map so that the line joining two points on the map coincides in direction with the line joining these same points on the ground. The subject of identifying on the map the position of points on the ground, and of identifying on the ground points shown on the map will be discussed later. For the present it will be assumed that such identification can be accomplished.

Orienting a Map by Compass. Any map fit for military purposes will show on its face the meridian lines, and will usually show the map direction of magnetic north, sometimes only the local data for the magnetic declination. If there is no magnetic

north line on the map, one should be drawn before the map is taken into the field. In other words, if it is intended to use compass orientation, there is as little excuse for forgetting to prepare the map for the purpose as there is for forgetting the compass. A little forethought is better than a lot of ingenuity.

Assuming, then, that there is a magnetic north line on the map, it is only necessary to set the N-S line of the compass parallel to it and shift the map until the needle is on the mark, when the map is correctly oriented.

Orienting a Map by Identified Points. Assume that two points a and b on the map have been identified as points A and B on the ground. Set the map at A and turn it until the line ab points in the direction of B. The map will then be oriented, and all lines on the map will be parallel to the corresponding lines on the ground. If it be desired to identify any other point X on the ground represented by x on the map, sight along the line ax on the map and the point X will lie in that direction.

If a map be set up over a known point and oriented by compass, the same results will be obtained, except that orientation by known points is more accurate.

Location of Points on the Map.

This subject has already been discussed to some extent in Chapter III, in connection with the subject of measurement of ranges for artillery and infantry. Some further phases of the subject will now be discussed.

General Accuracy of Maps.

In time of peace in the study of problems in strategy and tactics, the maps available will be general topographical maps resulting from formal surveys. At the opening of war, and at times thereafter when the scene of operations is shifting rapidly, the same character of maps will have to be used. In stationary or position warfare, there will be available both time and means

for the creation by the armies themselves of the special maps of large scale that are needed. The latter has been the case in many of the operations of the European War.

In either case, military men will have to deal with maps the general character and accuracy of which may be learned by inquiry concerning the date when the survey was made, the scale upon which the field work was executed, and the methods used in making the survey.

If the maps have already been in use for purposes of military operations, their maximum error in the location of points and their general trustworthiness as to representation of horizontal and vertical detail will have become a matter of common knowledge. These facts concerning the general accuracy of the maps should be learned by inquiry rather than through the perhaps costly process of experience.

Starting then with such information as can be gained by inquiry, the results of experience in the use of any given set of maps should be constantly kept in mind to check up or revise the estimate of their general accuracy.

Representation in Plan and in Elevation.

It is to be borne in mind that representation in plan, i.e., roads, streams, houses, etc., is practically entirely independent of representation in elevation by contours. Furthermore, representation in plan calls for no particular exercise of the imagination on the part of the topographer, whereas representation in elevation calls for both imagination and estimation, and the results achieved will vary greatly with the skill of the topographer.

A sharp distinction should therefore be drawn between the plan of the map and its contours in considering its accuracy.

In a general way, the plan of a map resulting from survey methods may be accepted as accurate within the limits imposed by the scale of the field work, and with due caution as to the date when the survey was made because of possible later changes in

roads, houses, and vegetation in general. The addition of horizontal detail to a map from airplane photographs can be done with a good degree of accuracy, because of the checks from roads and other points known in plan.

The representation of ground by contours is a very different problem. This representation is badly cramped on all except the large scale maps, and it is therefore generally impossible to draw the minor forms even if the necessary measurements could be made to locate and delineate them. Furthermore, there are ground forms over the whole area of the map, whereas the horizontal detail is limited. From these causes it results that the representation in elevation is far inferior to that in plan even in the larger scale maps, and this inferiority is accentuated as the scale becomes smaller. There is the additional difficulty that airplane photographs are of little assistance in the representation of ground forms. Vertical photographs reveal practically nothing of the shape of the ground, and oblique stereoscopic views but little more. Thus the airplane photographs serve to correct the representation in plan within the enemy's lines, but not in relief.

Identification of Points on the Ground.

From the above discussion, it is apparent that in the process of identifying on the ground points shown on the map, the points selected should be those in plan rather than those delineated by contours. And of those shown in plan, the order of accuracy will be:

1. Triangulation points;
2. Points on principal traverses;
3. Points on secondary traverses;
4. Interior points.

Finding Your Own Location on the Map.

If it be required to find your own location *accurately* on the map, then the problem is that of plotting your position by suitable measurements to points that can be accurately identified.

The problem is frequently that of finding *approximately* your position on the map, in order that the map may be oriented and the ground studied from this point in connection with the map.

The problem of finding your own location on the map varies greatly with the scale and detail of the map, as will be explained later. It may be assumed, however, that the problem is never wholly without known factors. Thus, if you are on the ground with the map in your hand, it is to be presumed that you remember something of how you got there and where you came from, otherwise there may be some difficulty in finding your location on the map.

In the problem of finding your location on the map, it may properly be assumed that you know approximately where you are to start with. Then it is only a question of identifying on the map the features which you see around you. If you have been following a road, this road is on the map and may be identified. The direction of the road, stream crossings, houses, and ground forms are examined on the map to see where you are. If the map is so poor that the features cannot be identified, or if you know so little of maps that you cannot recognize the map representation of these features, the situation is practically hopeless. Either a new map or a guide is needed.

In case you desire your map location off the road, the point where you leave the road should be identified, the map oriented roughly by the direction of the road, and some decision made as to approximately where you intend to go, for instance to some hill or valley or any other selected point. The direction and distance to the desired location are then known, and you will know by your watch about when you will get there. Knowing approximately where you are on the map, it is again merely a question of identifying the features about you.

The safe course in finding your location on a map is to keep track of where you are. A little care will save a lot of hunting on the map.

Relation of Map Scale to Detail.

There is perhaps nothing in the whole subject of map reading more important than a knowledge of the relation that exists between the scale of a map and the general character and accuracy of the detail shown on it.

Horizontal Detail. The conventional signs which represent the horizontal detail must be drawn large enough to be seen and recognized easily, for military maps must frequently be used where the light is poor. The amount of detail that can be shown in a given map area is thus strictly limited.

Difficulty in horizontal representation begins to be encountered on maps of surprisingly large scale. It might be thought that on a map scale of 6 inches = 1 mile, or its metric equivalent $\frac{1}{10,000}$, the 36 square inches representing each square mile would offer ample space in which to draw all the desirable detail.

On the scale 6 inches = 1 mile, $\frac{1}{50}$ of an inch represents a distance of approximately 18 feet. Thus a road or a house can actually be drawn to scale, though it is desirable to draw them approximately double their scale dimensions in order that they may be seen easily. A double track railroad symbol occupies a scale width of about 50 feet, so that it becomes evident that there is none too much room on this scale.

But it is in the vegetation symbols that the difficulty becomes more evident. The symbols for orchards, corn, cultivation, grass, woods, and the like, can hardly be readably executed in a space less than about $\frac{1}{2}$ inch square, yet $\frac{1}{4}$ square inch represents a ground area of about 5 acres on a scale of 6 inches = 1 mile.

From this it is seen that this scale permits of the accurate representation of the roads, railroads, houses (except in villages), and stream courses, none of which, with the exception mentioned, occur in such numbers as to cause difficulty on account of the exaggerated scale of their conventional signs. But in the woods, orchards, cornfields, etc., it is seen how im-

possible it is to represent the ordinary farm orchard, the small clumps of trees, the two-acre cornfield, and the like. The 6 inches = 1 mile scale must therefore be understood as showing only the wooded areas which exceed 5 acres in extent ,and even then their outlines are not necessarily accurately shown. The presence on the ground of many small clumps of trees and of much other horizontal detail of minor character not shown on the map should, therefore, occasion no surprise.

As the scale of the map decreases, the difficulties of representation increase rapidly. More and more of the less important detail must be left out, and that which remains must be more and more generalized.

If we take 1 inch = 1 mile as a typical small scale map, the difficulties of representing horizontal detail become apparent. The railroads will usually be not so numerous as to cause difficulty, and their alignment can generally be closely followed, but yards, switches, cuts, and fills can no longer be shown. Isolated houses are usually shown, but the straggling village has to be represented by a few house symbols. The principal roads can be shown, but many of the minor changes in direction and sinuosities must be omitted. Many of the minor roads may be crowded out, and usually no attempt is made to show trails and paths, except in mountainous country where communications are few. Vegetation symbols are usually omitted entirely. and if used show nothing more than the location and general outline of the principal forest areas. Thus in the 1 inch = 1 mile map, the plan is stripped almost bare of detail.

One important point must be remembered. The adequacy of horizontal representation on any scale is dependent upon the character of the country represented. If there is little detail to be shown, if there is but an occasional railroad, if roads are few, and if other detail is similarly lacking, a small scale may be adequate for representation, whereas a thickly populated region with its multiplicity of communications and other detail may

require considerable generalizations and omissions even on the larger scales. The general character of the country must therefore be taken into account in judging how faithfully it can be represented on any given scale.

Vertical Detail. The representation of the ground forms by contours has been seen to involve imagination and estimation on the part of the topographer. In small surveys, the contours may be run out and located instrumentally, but in general topographical surveys the topographer must locate a few points in position and elevation, plot these on the map, and then draw the contours. In the process the topographer is hampered by the limitations of the scale upon which he is working, and this limitation is just as severely felt in contour representation as it is in the representation of horizontal detail.

If we consider a map scale of 6 inches = 1 mile, there is the same difficulty that $\frac{1}{60}$ of an inch represents 18 feet, and this is accentuated by the fact that the contours must be drawn free-hand. It is therefore apparent that there is a great deal of minor vertical detail that cannot be shown by contours on a scale of 6 inches = 1 mile, or if attempted to be shown the result would be attributed to a tremulous hand.

In the representation of the ground by contours, the topographer is under the painful necessity of making some statement with respect to the form of the ground at every point on the map. He cannot discontinue the contours, and wherever they go they say what the shape of the ground is, and what is the degree and direction of the slope.

As the scale of the map decreases, the difficulties of contour representation increase. Soon a point is reached where all of the smaller valleys and spurs must be ignored, and only the main hill and valley features portrayed.

A very vivid illustration of the effect of the map scale on both horizontal and vertical detail may be had by comparing a large scale map with a small scale map of the identical area. Thus in

Fig. 30, the area represented in the left-hand part of the figure on a scale of 6 inches to the mile is the same as that shown in the dotted rectangle in the center of the 1-inch to the mile map shown in the right-hand part of the figure. The V.I. of the 6 inches = 1 mile map is 10 feet, that of the 1 inch = 1 mile is 50 feet. These maps serve to shown that practically all of the detail has disappeared in the 1 inch = 1 mile scale, and it is seen how impossible it would be to locate any position on the 1 inch = 1 mile map by identifying it by the shapes of the contours except in the case of sharp summits.

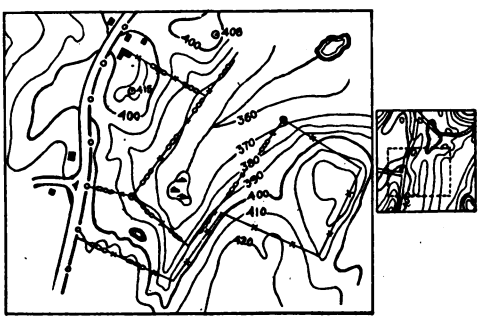


Fig. 30.—Relation of Scale to Detail.

The difficulties of representation on the map, both of horizontal and vertical detail, can be learned best by attempting the work in practice. After such practice, the student will be better prepared to make proper allowance for the inaccuracies and generalizations that exist in the best of topographical maps, and will understand better the limitations in the uses of maps.

Use of Compass with Map.

The orientation of a map by compass has been described. The other principal use of the compass in connection with maps is for the purpose of following on the ground either by day or by

night, a line laid out on the map. Usually this line will be the course to be followed on the ground to reach a given point. It may be either straight or broken, but there should be as few changes of direction as possible, particularly if the course is to be followed by compass at night.

When such a course is laid out on the map, the measurements of the lengths and directions of its different courses must of necessity be referred to the lines printed on the map—either the true north lines or the lines of the grid. It is necessary then to be able to translate such a description into terms of compass readings and distances.

Compass Bearings. The compass bearings or magnetic azimuths will differ from the true azimuths by the amount of the magnetic declination. It has been seen that the data with respect to the magnetic declination may be on the map, may be learned by local inquiry, or may be determined on the ground, and they are therefore assumed to be known.

The azimuth or true bearing of a line is the horizontal angle between it and the true north line. These azimuths are measured continuously around the circle from the south point around through west, north, and east. As indicated in (*a*), Fig. 31, the azimuth of directions between south and west are from 0 to 90 degrees, between west and north, 90 to 180 degrees; between north and east, 180 to 270 degrees; and between east and south, 270 to 360 degrees. The north point may be used as the origin, measurement being made in the same direction. Which origin is used will depend upon the graduation of the compass to be used. Thus if the compass is graduated from the north as zero, the azimuths of the courses to be followed should be similarly calculated.

The relation of the magnetic azimuth to the true azimuth will be seen by reference to (*b*), Fig. 31. Let us assume that the magnetic declination is 14 degrees west, its present value in northern France. Then if the true azimuths are anywhere between

0 and 346 degrees, the magnetic azimuth will in each case be 14 degrees greater. Particular note must be made of the true azimuths between 346 and 360 degrees. It will be seen that the line with true azimuth 347 degrees has a magnetic azimuth of 1 degree, 348 of 2 degrees, etc., and for the true azimuth 0 degree, the magnetic azimuth is 14 degrees.

Some compasses are graduated in quadrants, which complicates the situation considerably. A full discussion is unnecessary.

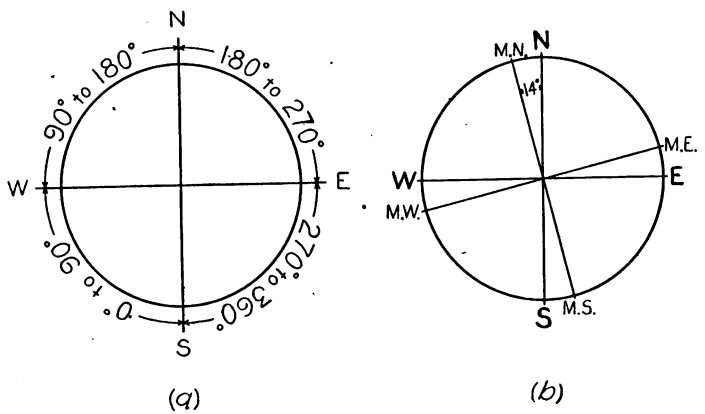


Fig. 31.—True Azimuths.

A diagram like (*b*) Fig. 31, will show how to convert true azimuths into magnetic azimuths or bearings.

Instead of the angle with the true north being used, it may be more convenient to use the angle with the north lines of the map grid, called *grid north.* In this case the angle between magnetic north and grid north is known or measured, and the magnetic bearings are calculated as before.

Marching by Compass. Having ascertained the compass bearings and lengths of the courses to be followed, the problem is to follow these courses either by day or night as may be required.

Following the course by day offers little difficulty. With the compass in position for reading its bearing, turn until the desired bearing is indicated, and the sighting line will show the direction. Note some distant point on this line upon which to direct the march. Follow this direction until the turning point is reached. This may be recognized by its map delineation, but the distance traveled should be kept track of as a check. Lay out the next leg of the course in the same way.

Marching by compass by night is more difficult. A compass with luminous markings must be used to find the direction. If there is enough light to be able to pick out some point on the horizon to march by, this is done. Otherwise one man with a spot of luminous paint on his back is sent forward a short distance and placed on the line by compass. Then the man with the compass goes to the spot thus marked and prolongs the line in the same way. Careful track is kept of the distance covered, as turning points cannot be recognized in the darkness and can only be known by distance.

If this process of following a compass course at night is to be used to guide marching troops, men must be posted at intervals along the route to keep touch between the compass man and the head of the column of troops. These men open out or close up as may be necessary to preserve the connection between the compass man, who moves forward irregularly, and the troops following at a regular gait.

CHAPTER X

TOPOGRAPHICAL MAPPING

INSTRUMENTS AND METHODS

Mapping Methods.

THE methods by which horizontal detail is located may be dismissed with little discussion. It requires no imagination to see a road, a stream, or a house. To locate these, all that is required it to make the necessary measurements with whatever instruments have been provided, plot the point or points so located, and draw the conventional signs representing the proper objects. The accuracy of the measurements will depend upon the instruments used, but a very fair degree of accuracy can be secured by skill and care, even with improvised instruments. The accuracy with which the plotting can be done and the amount of detail that can be shown are both dependent upon the scale of the map.

The representation of the form of the ground is a very different and much more difficult matter. It is impossible to take the time to mark out contours by points located with a level, and then to make the measurements necessary to plot the contours so marked.

All that is possible in the general case is to locate in position and elevation a comparatively few points, and from these few known points the topographer must draw the contours to represent the ground forms. The representation will be easier and more accurate if the points which are located are chosen so as to give the best opportunity to see the ground forms.

Even in elaborate surveys, where the primary control is by triangulation, the secondary control by instrumental traverses, and the filling-in is done by instrumental methods, the representation of the ground forms by contours depends finally upon the ability of the topographer to draw the contours with only a few located points to guide him in this work.

There are thus two fundamental elements in topographical work:

(*a*) The location of points in plan and elevation.
(*b*) Representation of ground forms from located points.

The location of points in plan and elevation is merely a matter of instrumental measurement, requiring only facility in the use of instruments and ability to make calculations and plot the results. The instruments by means of which points are located in plan and elevation in sketching methods will now be described, together with the actual methods of plotting lines and making measurements with these instruments.

Standard Sketching Equipment.

Military mapping must frequently be done in a minimum of time. The equipment used and the methods adopted must therefore be such as to afford results of reasonable accuracy with economy of time. As in all other military operations, economy of labor is of secondary importance.

As a result of all the attention given to the subject of topographical methods, opinion in our military service finally crystallized in favor of the plane-table method of sketching. The advantages of the plane-table as an instrument for topographical filling-in are well known. It affords the means of making all necessary measurements, furnishes the plotted positions of the selected (control) points immediately, and enables the topographical representation to be done by the topographer on the ground.

The standard plane-table is, however, both heavy and bulky.

The military equipment for topographical sketching must be light and easily portable, even at some sacrifice of accuracy, and must be available for mounted as well as dismounted use.

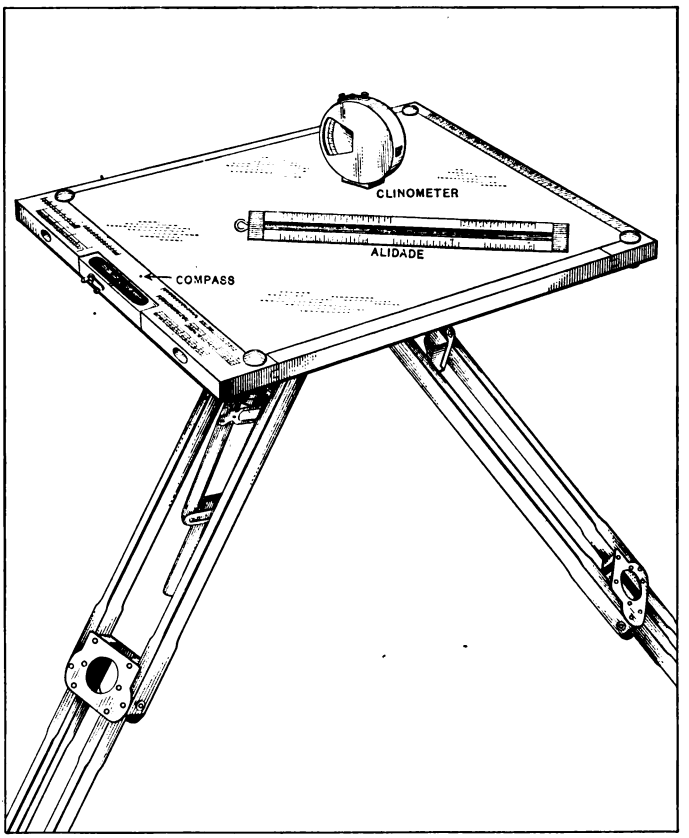


Fig. 32.—Standard Sketching Board.

Balancing these considerations, the equipment adopted for topographical sketching is the Engineer Sketching Board and its accessories, as shown in Fig. 32. The full matériel composing

a sketching unit is packed for field service in a convenient carrying case, which carries also a full reserve of paper and other supplies.

The principal items of this equipment are the sketching board and tripod, the alidade, and the clinometer.

Sketching Board and Tripod. The sketching board is of white pine, 14 inches square, with reinforce strips on the ends to prevent warping and splitting. A trough compass with $3\frac{1}{2}$-inch needle is let in flush with one edge. There is a small lever for raising the needle from the pivot. On the corners of the board are 4 clamp screws for securing the paper to the board. Along the edge by the needle are stamped an inch scale and plotting slope scales. On the opposite edge is a tangent scale with center near the edge of the compass box, from which a weight may be suspended and the tangent scale used for reading slopes. The edge of the board is the sighting edge for this purpose. At the corners of the board are holes for a carrying cord. In use, the carrying cord should pass from the outer left-hand corner of the board over the left shoulder and under the right arm to the inner right-hand corner of the board. The cord is adjusted to hold the board at a convenient height for use.

The tripod is of the folding type, substantially made of hard wood. The two pieces forming the upper joint of the leg swing outward on hinges and are sprung inward and engaged on two pins on a lug on the tripod head. When engaged these pieces are held in position by a spring clip. The lower joint of the leg slides outward and is clamped by a screw.

The tripod head is of three-ply veneer, has three lugs for the attachment of the legs of the tripod, and is provided with a clamping screw to attach the board to the tripod. The upper surface of the tripod head is provided with a felt pad for security in clamping.

Alidade. The alidade is of boxwood, $9\frac{1}{2}$ inches long, suitably weighted with lead, and of triangular cross-section. The edges are faced with celluloid, and upon these faces are stamped an

inch scale, scales of hundreds of yards for 1, 3, and 6 inches = 1 mile, and plotting slope scales. Two edges are left blank for the addition of a stride scale and trot and walk scales.

Clinometer. The service clinometer is non-magnetic and of the pendulum type, provided with stop and release. The scale is attached to the pendulum and the part of the graduation near the line of sight is reflected in a small mirror so that it can be seen while sighting with the clinometer. The line of sight is marked by a black line showing on a piece of white celluloid at the edge of the sighting opening. The scale is graduated in degrees, the graduation being in red on the plus or upward slopes, and in black on the negative or downward slopes. Slopes can be read by estimation to the nearest quarter of a degree. The clinometer is tested for mechanical condition by watching the swing of the arc when released to see if it swings freely and runs true. The clinometer should be tested daily for index error by reading forward and backward as accurately as possible on a selected slope. The mean of the readings is the correct degree of slope, and from this the index correction is determined, + if the upward reading was smaller than the mean value, and − if larger. The index correction is added algebraically to all readings.

Accessories. A pace tally forms part of the equipment, but its use is not recommended because it is not made of non-magnetic metal. A woven web pocket is provided, with suitable places for carrying the alidade, eraser, and pencils. The eraser is more conveniently carried attached to a clamping screw at one corner of the sketching board by a string about 15 inches long. There is a timing pad for use in mounted work. A pad of sketching paper and an envelope containing sheets of celluloid with ground-glass surface on one side complete the equipment.

Improvised Sketching Equipment.

If necessary to use improvised equipment, it should approximate as nearly as possible to the standard equipment.

The board can be provided without trouble. A pocket compass can be permanently secured to the board in any convenient manner, usually in a recess cut out for the purpose. The method of attaching the compass will depend upon the type of compass available. The needle stop must be left accessible.

The triangular alidade can be improvised and may well be only 6 inches long. The main difficulty will be its lack of weight and the consequent likelihood of being blown off the board. The necessary scales are made and pasted on its edges. The slope board can be used as a substitute for the clinometer, and with careful use will give quite as accurate results. The main difficulty in the use of the slope board is that vertical angles cannot be read while the board is in position, and consequently all vertical angles must be read either before the board is set up or when ready to leave the station. This is merely a matter of inconvenience, however, but involves loss of time if any horizontal angles happen to have been omitted, as the board must then be set up again and oriented.

The tripod offers the greatest difficulty in the improvisation. Rotation and clamping should be provided for if possible. A camera tripod can be used, but generally its metal fittings are of magnetic metal. If a tripod or jacob-staff be improvised, brass screws should be used and not nails. Or the tripod idea may be abandoned and the carrying cord used. In this case, for important shots the board is removed from the carrying position and placed on the ground for orientation and sighting.

In general, the crudeness of the improvisation must be compensated for by additional care in the use of the instruments. The methods described for using the standard equipment apply as well to improvised equipment.

Using the Standard Sketching Equipment.

Sketching Paper. If tracing vellum or celluloid is used, it is necessary to put a piece of white paper (preferably bristol board)

underneath, otherwise the pencil lines cannot be seen against the board. For instruction purposes, a good grade of plain white paper can be used as well. Some practice should be had on the vellum and celluloid to learn the little peculiarities of both.

For the vellum, an F or HB pencil should be used. All temporary lines, such as plotted directions, elevations of points, and tentative contours, should be drawn in light lines so that they may be erased easily and cleanly. Permanent lines of the sketch, such as roads, fences, final contours, and the like, should be drawn with enough pressure (determined by test) to prevent clean erasure. On sketches so drawn the temporary lines can be erased without fully erasing the permanent work, which can then be restored.

For the celluloid, a 6H pencil is to be preferred, kept sharpened to a fine conical point. Frequent sharpening is necessary because the ground-glass finish of the celluloid wears away the point rapidly. A small sand-paper block should always be attached to the leg of the tripod by rubber bands for use in pointing the pencil. The tentative lines are drawn in light lines, permanent lines somewhat heavier, but both will disappear under the eraser. Erasing of tentative lines must therefore be done in small patches, the permanent lines being restored. Weight of line is secured on celluloid by going over the lines two or three times. For the finish of strong black lines, a softer pencil (2H) should be used. Avoid too heavy a pressure on the pencil, as it will cut a furrow in the celluloid, and several such lines close together will distort and buckle it.

Assembling the Sketching Board. The sketching board is dressed for use by attaching the paper, assembling and attaching the tripod, fastening a good eraser to one of the clamping screws by a string, and fastening a sand-paper pad or block to one of the legs of the tripod. Necessary pencils, alidade, extra eraser, and knife are carried in the web pocket, if available, otherwise in the pockets. The clinometer is carried in its leather case upon the

belt or in the pocket—*never* in the pocket without the case, or lint will get inside and put it out of commission.

Carrying the Sketching Board. Thus equipped, the sketching board is carried to the point where work is to be started, either on the shoulder or with the tripod under the arm. The latter is preferable in brush or woods. If carried on the shoulder, care must be taken that the board does not become loosened and fall off. If you hear anything rattling, see if the needle is properly clamped. It is ruinous to carry the needle loose on the pivot.

Setting Up the Sketching Board. At the starting point, the board is to be set up and oriented for use. Proper methods contribute greatly to the speed of work, and detract in no wise from accuracy, hence the methods described should be followed exactly.

In setting up the board, take one tripod leg in each hand and swing the free leg forward and place it on the ground. Now place one of the remaining legs of the tripod on the ground about 2 feet from the first. With the remaining leg level the board. Lateral movement will tilt the board sidewise, radial movement in the opposite direction. On sloping ground, always set two legs on the same level, the odd leg being extended uphill.

Orienting the Sketching Board. Before setting up the board, always look around to see if there is any object near which might disturb the needle. If so, the position must be changed. If the north is approximately known, turn the board so that the north end of the needle points approximately north, and then release the needle. If the north is not known, find the setting of the board by trial. The clamping screw of the tripod head should be set so that the board can be twisted by some little force, too much to permit the board to be displaced in use.

After the needle is released, the board is set approximately, so that the needle swings about equally each side of the black orientation line in the bottom of the compass box. After the needle has settled completely, the final adjustment of the orien-

tation is made. In doing this, the eye should be placed directly over the needle, and care taken to see that the extreme N. end of the needle is exactly in the middle of the orientation line. In this process of orientation, watch the needle carefully to see that it is not in contact with the glass, thus restricting free movement. It is an excellent plan to tap the corner of the sketching board either before or after the orientation is complete. If the needle is free and the pivot in good condition, the needle shows a characteristic quiver when the board is tapped. If the end of the needle is in contact with the glass, tapping the board causes the end in contact with the glass to fly down.

Alidade. The triangular alidade has two distinct uses:

1. As a sighting line and ruler;
2. As a plotting scale for both distances and slopes.

First Use. Assuming that the board has been set up and oriented, and that a point has been marked on the paper with a small circle drawn around it to indicate that it is a traverse station, everything is in readiness to plot the directions of any lines that may be desired in connection with the sketch.

To determine and plot the directions, it is necessary to place the alidade in position on the board, with its edge accurately upon the traverse station, and then, keeping the edge of the alidade over the station, to point the alidade so that by sighting along its upper edge the distant object is seen accurately in prolongation of it.

The difficulty is in keeping the edge of the alidade over the station while making the pointing. The pointing should be made with the eye at the level of the board, whereas the eye must be above this level to see if the edge passes through the point. The best method is first to point the alidade as nearly in the direction of the object as can be done while looking down on the board. As an aid, point the finger at the distant object and adjust the alidade parallel to it. Then take a squatting

position with the eye near the edge of the board and correct the pointing; rise slightly so that the point can be seen and adjust to the point without disturbing the direction; check the pointing and repeat if necessary. Draw a line along the edge of the alidade through the traverse station, and this is the plotted direction of the distant point. If the sight is much inclined, set a pencil on the board in a vertical position at the forward end of the alidade if sighting upward, at the rear end if downward, to assist in making the pointing. Watch the pencil to see that it remains vertical.

Second Use. The alidade is used to plot the distances that are paced during the work of sketching. The length of stride is computed and the working scale of strides is constructed as described in Chapter IV. This scale is now transferred to the edge of the alidade. After distances have been paced, the edge of the alidade is placed along the plotted line and the number of strides is plotted from this stride scale.

It has been seen that the edges of a standard alidade are marked with plotting slope scales. These slope scales show, on a scale of 6 inches = 1 mile, the map distances between 10-foot contours for various degrees of slope. These scales may be used either for marking directly the distance between contours on slopes, or for determining the elevation of any desired point which has been plotted in horizontal position on the sketch.

In plotting the actual contour points with the slope scale, the plotting must start from some point on the slope the elevation of which has been determined, as say, 226 feet. Suppose the slope upward from this point is 3 degrees. Then the 3-degree scale is applied in the direction of the slope with $\frac{4}{10}$ of the contour interval only above the 226-foot elevation, so that the first point marked will have an elevation of 230 feet. From there on the full 3-degree interval is plotted for the spacing.

In plotting the elevation of points on traverses, or points located by intersection or other methods, the slope of the line

to the point must be read from some known elevation. Suppose in a traverse, that we have a station of elevation 387 feet. A sight is made to the next station forward, a slope of 2 degrees read, the distance paced, and the new station plotted in horizontal position. The 2-degree slope scale can be applied to this line exactly as if it were a uniform slope and the number of 10-foot intervals counted, thus determining the difference in elevation between the two points, the forward point being higher if the vertical angle is plus, and lower if minus. Instead of computing the difference of elevation between these points and then having to add or subtract this distance, it is more convenient to set a partial interval, $\frac{3}{10}$ in the above case, and then count forward by contour intervals and estimate the fractional interval at the end, so that the elevation of the forward point thus becomes known directly without any addition or subtraction other than has been done in counting up or down the slope.

If a point has been located off the traverse by intersection from two points on the traverse and the slope read to the intersected point from each of the traverse points, the elevation of the intersected point could be determined by using the slope scale on the line from either traverse station. In practice it is computed from each of the stations and the mean value of the elevation used.

Clinometer. In using the service clinometer, a very considerable degree of care is necessary to secure accurate results. The clinometer must be held in a steady position which is difficult, particularly in a heavy wind. It is best to rest the arms against the body and the edge of the clinometer against the face, so as to get as much support as possible for the arms and hands. The pendulum is released by pushing back the locking slide and then pushing down upon the release stop. The pendulum is free to swing only while the stop is pushed down. The stop should therefore be held down until the pendulum has come to rest and the reading has been completed. There is a certain amount of

jump of the scale noticeable when the stop is released, and this would affect the reading. In reading any slope with the clinometer it must be remembered that the clinometer is held at a distance of about $5\frac{1}{2}$ feet from the ground. To measure the actual slope of the surface of the ground, the sight must be made at a point as high as the eye above the ground. With such a reading the correct relative difference in elevation will be determined. If we stick rigidly to sighting at a forward point $5\frac{1}{2}$ feet above the ground, the angle so read will often include a quarter-degree reading or some other degree not found on the slope scale, as $6\frac{1}{2}$, $2\frac{1}{4}$-degrees, etc. The differences in elevation corresponding to a $6\frac{1}{2}$-degree slope may be considered as composed of a $3\frac{1}{2}$-degree slope added to a 3-degree slope. The difference due to each may be found separately and the two added. The $2\frac{1}{4}$-degree slope may be considered as a 2-degree slope plus $\frac{1}{4}$ degree. The $\frac{1}{4}$-degree difference in elevation is computed by using four times the 1 degree interval on the scale. It is, however, a great saving of time when the true reading is some degree and fraction not on the slope scale, to take advantage of this latitude offered by the height of the eye, to read an angle which *is* on the slope scale, correcting the result by what is seen through the clinometer. Thus, if the forward slope is plus $2\frac{1}{4}$ degrees when the point sighted at is estimated to be at the height of the eye above the ground, it is well to see where the line of sight passes for a 2-degree slope. For a 2-degree reading, let us suppose that the line of sight passes at an estimated distance of 2 feet above the ground at the point sighted at. It is then merely necessary to remember that the point is actually $3\frac{1}{2}$ feet higher than it would have been if the slope had been exactly 2 degrees. It is much simpler therefore to use a 2-degree reading and add $3\frac{1}{2}$ feet to the elevation.

It is difficult to read very small slopes near 0 degree. The difference in level in this case, except for very long shots, is only a few feet. This difference of elevation can probably be more accurately estimated if a 0-degree reading (=level) is made

from the higher of the two points, and the distance above ground at which the line of sight passes at the lower point is estimated. The height of the eye must be subtracted from this estimated height to get the difference of level. If the difference of level of the two points is less than $5\frac{1}{2}$ feet, it is better to make the 0-degree reading from the lower point.

A careful topographer will test his clinometer daily, handle it carefully, and never release the stop in such a way as to allow the pendulum to swing violently against its stopping lugs. Used carefully, reading the vertical angle forward and backward on the principal long shots, and taking the mean with careful pacing of distances, there should be no difficulty in keeping the error in elevation within 5 feet to the mile of traverse. Such an error will offer no difficulty in plotting the contours.

Slope Board. In using the sketching board as a slope board for the measure of vertical angles, either the alidade or a lead bob is suspended by a string about 15 inches long passed through a hole near the compass box and knotted on the under side of the board. The lead bob is much to be preferred, because it is next to impossible to check the swinging of the suspended alidade if the wind is blowing.

To read a vertical angle with the slope board (right-handed man), gather the legs of the tripod together and hold them in the left hand at the balancing point. Rest the left elbow firmly against the body, the feet spread well apart. Sight forward along the compass box edge of the sketching board to a point the height of the eye above the ground at the forward station. The right hand must be relied upon to find by the sense of touch when the bob has stopped swinging, to shield the bob from the wind, to see that the string is not rubbing against the edge of the board and thus damping the motion of the bob; and, when all of these conditions are satisfied, then to press the string against the board without slipping until the reading of the angle is made. This is a large contract for the right hand to fulfill. To accomplish it

the forefinger is placed against the lower edge of the board beyond the point where the lead bob will hang. The fingers are spread around the bob to protect it from the wind and the little finger used very carefully to touch the bob to see whether it is swinging. The thumb is used to touch the string lightly to be sure that it is swinging clear of the face of the board. When these conditions are fulfilled and the line of sight is correctly adjusted, the string is pressed against the board by the thumb, the tripod legs turned downward, so that the board is brought to a horizontal position, and the angle marked by the string is then read. This vertical angle is, of course, used in the same way as a clinometer reading.

Skill in the use of the slope board requires considerable practice. This practice should be continued until the same reading can be repeated without difference.

CHAPTER XI

TOPOGRAPHICAL MAPPING—Continued

TRAVERSING—SELECTION OF CONTROL POINTS—CONTOUR PROBLEMS

Traversing with the Sketching Board.

BY continuing the operation described in the preceding chapter, a traverse results. Starting from an initial point the elevation of which is known or assumed, the sketching board is set up, levelled, and oriented. The directions to the point selected as the next traverse station and to such side points as it may be desired to locate are plotted, and the slopes are read along the various lines. If there are any slope lines that will be of value in plotting the contours, such lines are located by approximate pointings of the alidade. Either a memorandum record of slopes and identification of points is made along the plotted lines, or the shots are lettered and the memorandum is made on the edge of the paper. Having completed this work, the needle is raised from its pivot (*important*), and the distance is paced to the next traverse station. Upon arriving at the station, the number of strides may be jotted down on the edge of the paper or remembered, and the board then set up, levelled and approximately oriented. The stride scale of the alidade is now used to plot the distance, and the second traverse station is marked and its elevation computed by using the slope scale and the vertical angle previously read. The orientation of the sketching case is now made exact. Intersecting shots are made on the points located from the first traverse station, and on such additional points as will be visible from the third station. The

slope of each shot is read and recorded. The elevations of the points located by intersection from the first and second stations are computed. The needle is now raised from the pivot (*still important*), and the traverse continued at will. As a test of the accuracy of the elevations as well as of the traverse in plan, the traverse should be made finally to close upon the initial point. The error of closure, using the standard sketching equipment, should not exceed about ten strides per mile of traverse, and the error in elevation should not exceed about 5 feet per mile. With improvised equipment the errors may be greater due to difficulties of manipulation. The result of such a traverse will be the location of a series of points the elevation of each of which is determined, together with important slope lines.

If the traverse should pass along the crest of some commanding ridge, the plotting of direction may be made with special care, the pacing of the distance repeated to get the mean value, and a special effort made in every way to make this section of the traverse as accurate as possible. The two ends may then be used as a base line from which as many points as may be desirable are located by intersection, thus plotting the resulting points with approximately the same accuracy as the base line. Such a system of points will form the frame-work for a "base-line" sketch of the area.

Locations by Resection. If the two ends of the base line are marked by some objects such as trees or telegraph poles that may be seen from points off to the side, then additional points can be located by the method known as resection. To locate a point by resection, the sketching board is set up and oriented accurately. Then a sight is made to one end of the base line with the edge of the alidade passing through its plotted position. A line is then drawn in the direction of the point occupied. Another similar shot is made upon the other end of the base line, and the intersection of the two lines so drawn marks the plotted position of the occupied point. The vertical angle to each end

of the base line is then read and the elevation determined by the use of the slope seale.

Whether the whole system of points thus located by a traverse will be useful in making a contoured map of the area will depend upon the points that have been located. It is, therefore, very important to learn to select those points which will be of the maximum use in delineating the area by contours. Such points are called *control points.*

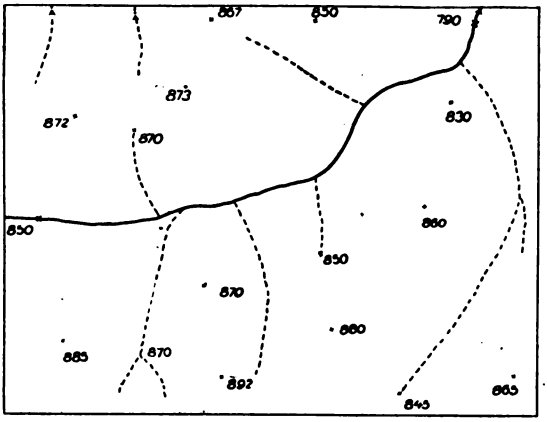
Contour Problems.

There is one class of problems which can be given indoors that forms an excellent preparation for the selection of control points in the field work by showing the sort of framework necessary for the delineation of the ground. These problems also give excellent practice in the working out of typical contour forms. Such problems are called contour problems, and the form of the data and the different steps in the solution of these problems are indicated in Figs. 33 and 34.

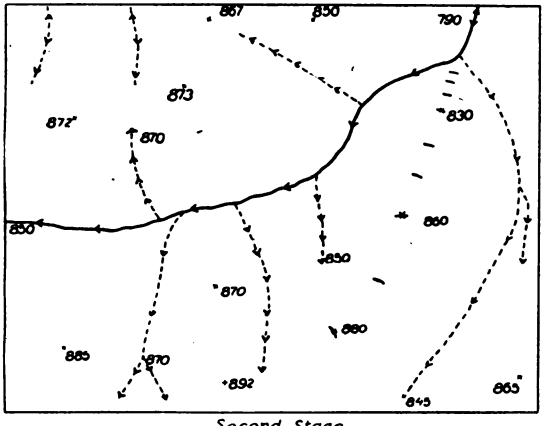
It is to be noted that the data are given in the form of a plan of the drainage system of the area, together with the elevation of certain points along the stream courses and the location and elevation of certain points on the intervening high ground. The theory upon which the problems are solved is that the data give the location and elevation of all points where the contour spacing changes.

If the slope along the stream course changes, the elevation at the point where such change occurs must be given. Similarly, if a change of slope occurs on the hills, the point where such change occurs must also be given. The location of the stream courses is the first and most important thing in the contoured delineation of an area, because upon the plan of the drainage system depends the whole shape of the contours along the stream courses, and these form the basis for working out the forms at the tops of the hills.

The method of solving these problems is indicated in the four stages shown in Figs. 33 and 34.



First Stage

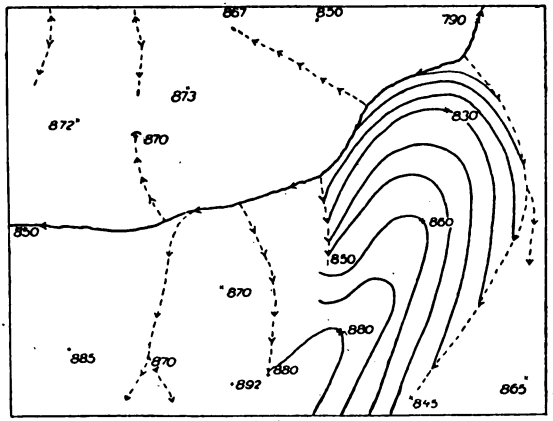


Second Stage

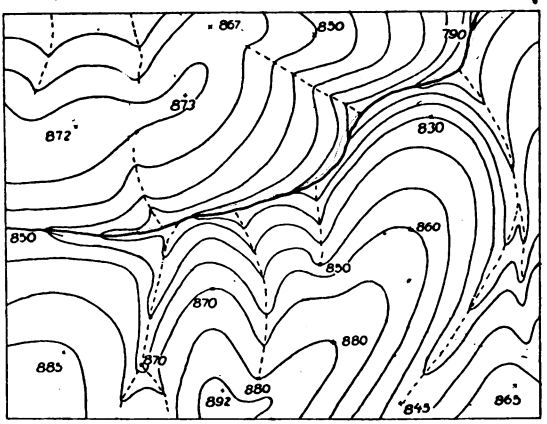
Fig. 33.—Solution of Contour Problems.

The first step is to determine, by interpolation from the elevations given along the stream courses, the points where the contours

cross the streams. This interpolation is done first along the principal stream courses, and then, using the elevations at the



Third Stage



Fourth Stage

Fig. 34.—Solution of Contour Problems—*Continued.*

mouths of tributaries determined by interpolating between the contour crossings on the main stream, the elevations are similarly

interpolated along the tributaries. In the absence of any other evidence it may be assumed that the dry valleys indicated by broken line tributaries all head at about the same general elevation below the crests. Consequently, the distance between the contours along streams can be estimated by the length of the indicated stream course. Having thus indicated the points where the contours cross all the streams and indicated wet-weather stream courses, the interpolation is next carried out between the stream courses and the points on the ridges. This interpolation can be carried out both upon lines from the ridge points perpendicular to the streams and also along the ridge or spur lines which extend in the direction of the junction of the including streams. If there be no intervening stream courses, interpolation can also be carried out along the ridge lines, curved or straight, which connect the points of given elevation on the high ground.

The result of all this interpolation is the location of such a number of points on each contour that the shapes of the contours themselves are very closely indicated, and if the type forms of valley, spur, and hill contours are followed, there will be little variation possible from the correct solution of the problem.

The result of the solution of a series of problems of this kind will be to impress upon the mind of the student the fact that *if the stream courses be correctly located* and the points where the slopes of the streams change are indicated, then the locations and elevations of a few points properly chosen on the intervening high ground will be sufficient for the contoured delineation of the area.

If the ground to be represented is the result of erosion from sedimentary deposits, the existence of uniform slopes and convex crests is to be expected and this, as a matter of fact, is the character of the country represented in Figs. 33 and 34, and also in Figs. 35, 36, 37 and 38, following at the end of this chapter, which are additional contour problems for solution by the student.

If the area to be represented is of other geologic forms, as for instance igneous rock, then the uniform slopes and smoothly

rounded forms so convenient for the topographer are much less likely to exist. The ground forms will be intricate and irregular, and a great many more interior points will be necessary for a satisfactory delineation of the ground. Even in this character of country, however, it is only necessary to locate the stream lines and a much greater number of intermediate points to enable the ground forms to be delineated.

In *very* intricate country, it may be necessary to resort finally to the ability to represent by contours a small area from any given point, and then locate enough points so that the representation will be continuous.

Contour problems for practice follow. The data for them should be traced on a piece of thin (or tracing) paper to be used for the solution.

NOTE.—The contour problems in Figs. 33–38 inclusive are selected from a series of problems of this character used for instruction at the Army Service Schools, Fort Leavenworth, Kansas.

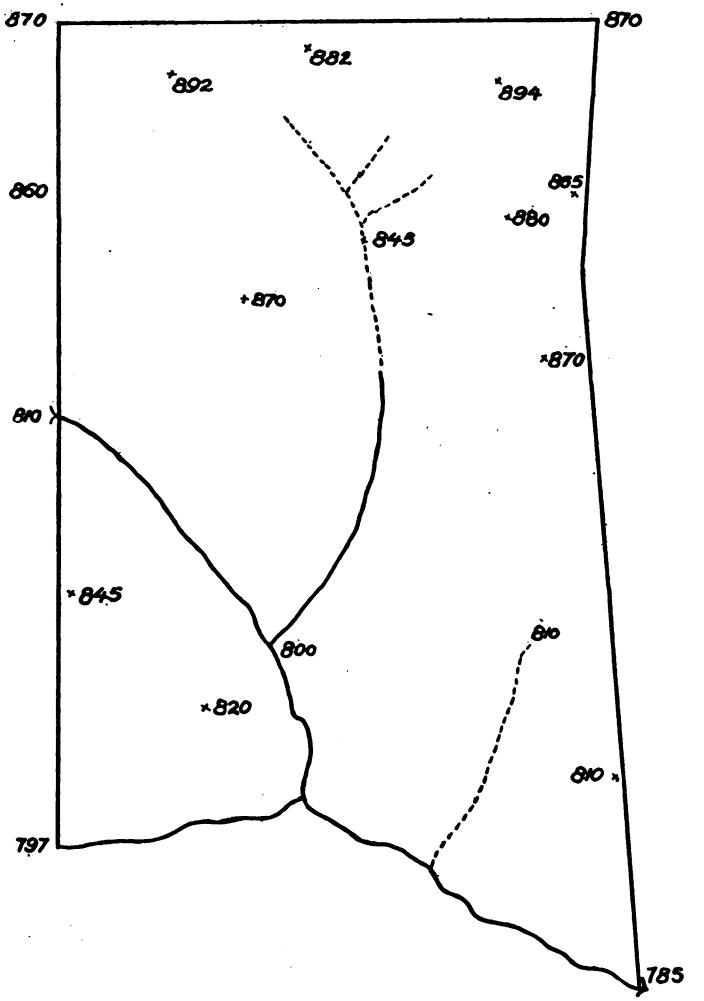


Fig. 35.—Contour Problem *A*.

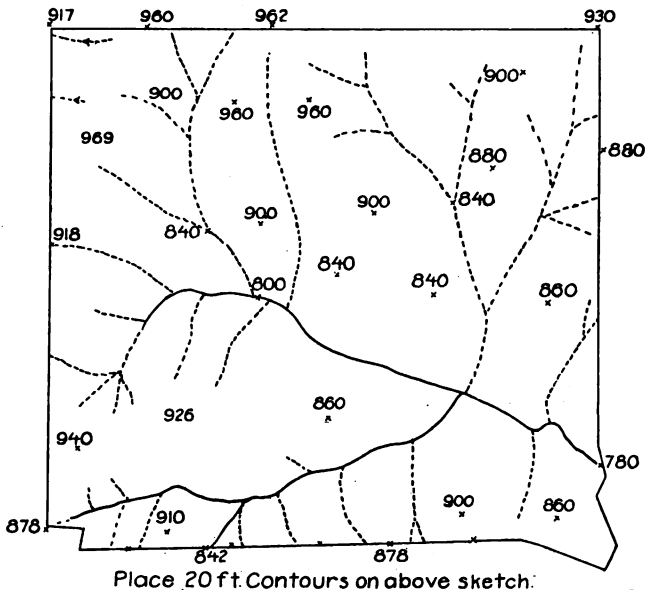


Fig. 36.—Contour Problem *B*.

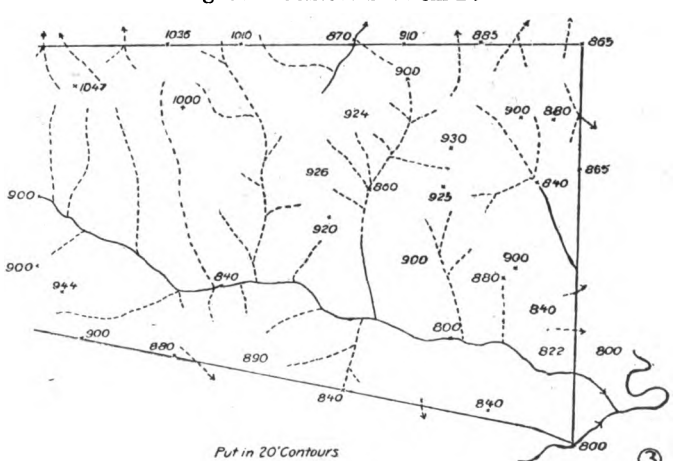
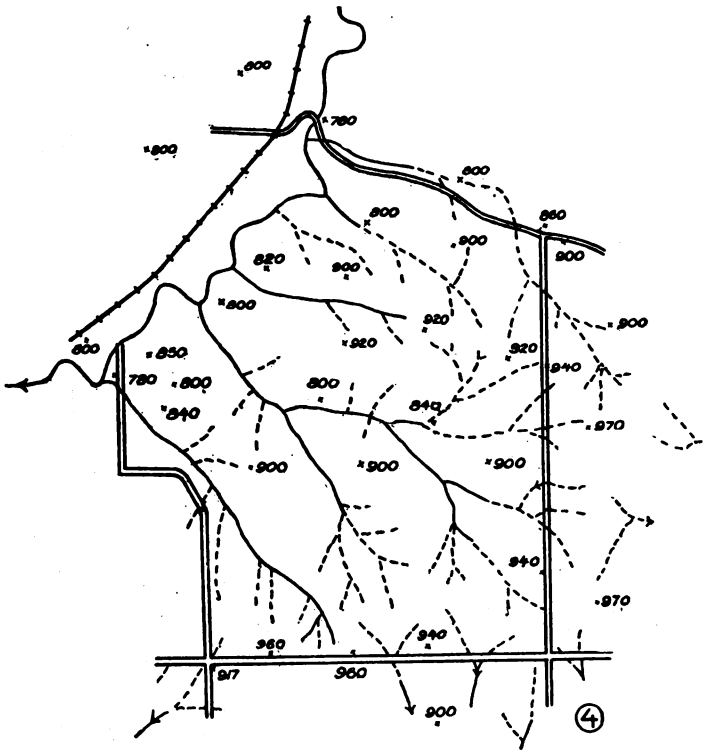


Fig. 37.—Contour Problem *C*.



Put in 20'Contours.

Fig. 38.—Contour Problem *D*.

CHAPTER XII

TOPOGRAPHICAL MAPPING—Continued

SKETCHING FROM A LOCATED POINT

Selection of Ground for Practice.

IN many cases there will be difficulty in selecting a suitable plot of ground for instruction in contouring. It is not necessary, however, to reject a piece of ground full of horizontal detail if it has the necessary variety of slopes, valley, spur, and ridge forms. For instruction purposes, the horizontal detail may be disregarded entirely so long as the buildings or trees are not sufficiently numerous to prevent getting a good view of the area. The worst possible condition of affairs is a piece of ground covered with thick brush or woods, and it should not be considered for instruction purposes, because it is impossible to get any view of any extent and consequently impossible to point out satisfactorily or prove the students' errors. A wooded area may, however, be used late in the fall or early in the spring when there are no leaves on the trees.

With these considerations in mind, an area of ground conveniently located is sought, about 1 square mile in extent, and possessing the best available characteristic ground forms. Other smaller areas may be used for preliminary problems.

Scale and Vertical Interval.

It is best to carry out the preliminary instruction of a student in sketching on a scale of 6 inches = 1 mile. Some favor the use

of 12 inches = 1 mile for preliminary instruction, because of the smaller amount of generalization involved. It is thought, however, that the student might as well face this problem of generalization at the start. The 12 inches = 1 mile scale slows down the work too much. The 6 inches = 1 mile scale gives a far better idea of proper progress.

Control Traverse.

As a preliminary to the work of contouring, the student should run a control traverse through the area, closing and checking upon itself. This control traverse gives an excellent opportunity to show the student how much reliance can be placed upon the horizontal location of points. If the standard equipment is available, the plotted positions of the points of the traverse will be out of position by little more than the plotting error of the scale. The ground points located by this traverse should be remembered by the student. From what has been seen before, it is essential that the traverse shall furnish all the data for plotting the stream courses and drainage lines accurately. All is now ready for the delineation of the contour forms from the located points, and the student should be reminded that the only difference between what he has done and a formal survey lies in whatever inaccuracy there may be in his location of points, and that he now has the same opportunity to represent the ground faithfully from any given point as has the topographer in a formal survey.

Analyzing Ground Forms.

As a preliminary to the work of delineating the small area about a located point, the student should see accurately just what there is to be shown. If he is at the top of a summit, he must look for the beginnings of spurs and valleys, and note that the direction of these features is of importance. If in a valley, the character and degree of slope at the sides of the valley should be noted,

also the direction of any minor spur or drainage line which would affect the contour forms. If among the indistinct ground forms lying near the crests there are any features that may serve to mark or distinguish the point, such as the beginnings of valleys or spurs, they should be noted. In other words, at any point from which sketching is to be done, the student should ask himself what he would have a right to expect to find on a good map of the area immediately about him, and if there is any feature which belongs on such a good map, then the student must be prepared to show it in its correct form and position upon his own sketch.

Specific Example. Fig. 39 (1). In order to illustrate what is done at a single point, it is best to consider the procedure at a

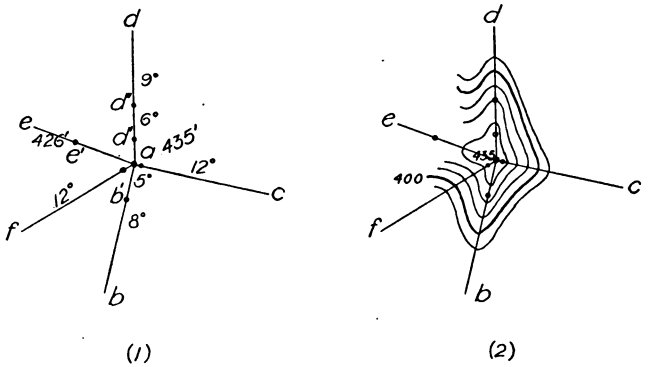


Fig. 39.—Sketching from a Point.

point marked by characteristic ground forms. Such a point is represented at *a*.

With the board set up and oriented at *a*, elevation 435 feet, inspection shows that there is a spur running in the direction of *b*, the crest of which is sharp, and that it changes slope at some point, as *b'*, not yet determined; that in the direction *c* there is just enough in the way of a spur that the contours between the lines *c* and *b* are concave rather than convex in plan; that in

the direction of *d*, the axis of the ridge is level to some point *d'*, and that the spur changes slope at some point *d''*, both points not yet determined; that in the direction *e*, this knoll at *a* is joined to other high ground by a saddle; that the contour forms between the lines *d* and *e* begin to show a valley; and that in the direction of *f* is a rounded depression such that the contours are nearly semi-circular in form. This analysis of the ground is made by walking around from *a*, as may be necessary, and the result is to come to a definite conclusion as to just what is to be shown about *a*.

Measurements from the Point. Fig. 39 (1). Having determined just what is to be represented, the necessary measurements are evident. First the lines *b*, *c*, *d*, *e*, and *f* are plotted. Refinement in making these pointings with the alidade is not necessary. In a general way, it is sufficient to point the alidade as accurately as possible without stooping down to the level of the board, since nothing depends on these shots but the plotted direction of the axes of the features. In the direction of *b* the slope is now read for the first part of the slope, and found to be 5 degrees. Pacing in the direction of *b*, the 5-degree slope ends at 30 strides at *b'*. Here the slope is read in the direction of *b*, and found to be 8 degrees, certainly as far down as the fourth contour below *b*. Returning now to *a*, after going 5 strides in the direction of *c*, the slope is measured and found to be 12 degrees, for at least four contour intervals. In the direction of *d* the axis of the ridge is level for a distance of 20 strides to *d'*. Then begins a slope of 6 degrees, to the point *d''*, 50 strides from *a*. At *d''* begins a 9-degree slope, extending down at least three contour intervals. In the direction of *e*, a slope of 2 degrees is read and the distance 52 strides paced to *e'*, which is the low point in this saddle. Its elevation is determined to be 426 feet. After striding 8 strides in the direction of *f*, a slope of 12 degrees is read and mental note made of the semi-circular form of the contours in this direction. The result of all of these measurements is a series of contour

points along each of the lines *b*, *c*, *d*, and *f*. It now remains to draw the contours through these points in such form as to follow faithfully the ground before us. The slopes between *b* and *c*, and *c* and *d*, are both concave in plan rather than convex. Drawing the contours according to what we have observed, the result is shown in Fig. 39 (2).

Checking Results.

After completing the delineation of the ground form, the result should be checked to see whether the representation is correct, showing the break in the slope in the directions of *b* and *d*, the very blunt spur in the direction of *c*, the saddle in the direction of *e*, the beginning of the valley between *d* and *e*, and the semi-circular form in the direction of *f*. If the representation answers all of these tests it is not likely to be the subject of criticism. The delineation above described is made to depend upon measurements, and a clearly marked hill form was selected to be delineated. It is not always possible to do the sketching in this way.

The Level of the Eye.

As soon as we begin to sketch by estimation, it becomes important to be able to select without instrumental aid a point on the ground at the level of the eye, and then by swinging the extended arm to describe a level line so that a satisfactory conception can be gotten of the trend upon the ground of a contour at the level of the eye. The ability to select, without instrumental aid, a point at the level of the eye is not a natural faculty but is one which must be carefully cultivated. Experience shows that with beginners in topography, if they are asked to point out a spot at the level of the eye, the average man will designate a point the actual reading on which is about plus 3 degrees. However, this tendency can be overcome by practice.

It is possible, with a little practice before the mirror, to extend

both arms in a horizontal position. If the body be swung upon the hips, eyes to the front, the hand will come into the line of vision on a level with the shoulder. If the thumb be turned up and fully extended, it will approximate to the level of the eye. Swinging the arms backward and forward in front of the eye in this position will give a good conception of the trace of the contour on the level of the eye. After considerable practice has been had, it is necessary to swing only one arm, and the result achieved will be quite satisfactory.

Sketching by Estimation.

Flat Hilltops. If instead of the clearly marked forms in Fig. 39, the hilltop had been comparatively flat, and the forms ill-defined, all we should have had to go on would have been an elevation of 435 feet at the location of the instrument, with nothing definite to read on in any direction. We will suppose that in a certain direction, after a distance of 50 strides, the ground begins to slope downward. We may plot that direction, and then, proceeding along that line, establish ourselves at a point such that the ground at the sketching board will be at the level of the eye. The clinometer might be used for this work, but it takes too much time. We are now standing on ground at 430 feet elevation. Mark this 430 point and proceed farther until the eye is on a level with it. Swinging the arm will now sweep the 430-foot contour on the ground. The total distance to the sketching case is known, having been paced in coming out, so that both the plotted position of the point occupied, and a direction line will be on the sketch to guide in drawing the contour. Its meanderings for 50 strides each side of the line with respect to the line to the sketching case should be noted for use in plotting the contour upon return to the sketching case. About three or four outward journeys like this may be necessary to get a satisfactory delineation of the 430-foot contour. The total time necessary is not over ten or fifteen minutes and is well spent,

because the correct working out of the form of the 430-foot contour will then form the basis for all the ground forms lying below.

Valleys. The valley contours lend themselves readily to the method of sketching by estimation. If we occupy a point on one side of the valley, we then judge the level on the other side of the valley to see whether the contour is symmetrical on the two sides of the stream, estimate or pace the distance to the stream, and thus establish two points on the contour. Swinging the arm at the level of the eye, the point is estimated at which the contour crosses the stream. This point is estimated in distance by comparison with the width of the opening across stream. As has been indicated, the beginner will be surprised at how close the contour is on the other side of the valley, and how far upstream it extends.

Hillsides. In sketching from a point located on the side of a hill, the slope up and down may usually be read, and the contour spacing and locations in these directions established. Trace the contour at the level of the eye to see the form which it follows, what indentations and other peculiarities there are in it. The form of this contour will guide the drawing of the map contours at the point. Always, before leaving a point, examine the sketch to see if any feature is omitted that should be shown; to see that every feature that is shown is in its proper direction from the traverse point; and in general, that the representation of the ground is as accurate and as detailed as it lies within your power to make it, subject to the limitation that it is no use to spend time making little sinuosities and indentations in the contours that do not give any definite and specific information about the slope of the ground and would merely be lost in the general use of the map. In this connection, it is well to remember that the slope of the ground at any point requires the contours both above and below it to completely show the character of the slope.

CHAPTER XIII

TOPOGRAPHICAL MAPPING—Continued

Estimation of Distances, Mounted Sketching, Etc., Lettering

Estimation of Distances.

It is very important for the sketcher to cultivate the ability to estimate accurately distances up to 50 strides. This faculty can be acquired with little difficulty, because practice can be had at any time the student is walking around. Objects ahead are selected and the distance estimated. This estimate is then checked by pacing the distance.

Until the ability to estimate distances accurately has been gained, it is well upon occupying a station where it may be desired to estimate distances, actually to pace the distance to some object about 8 or 10 strides distant. Then all distances to be estimated can be compared with this known shorter distance as a check.

Having learned to estimate distances on the ground accurately, it is next desirable to be able to set off on the map distances up to 50 strides without the use of the stride scale. It will be found that this can be done with satisfactory accuracy after a little practice.

The student should practice until able to estimate distances accurately on the ground, i.e., within 10 per cent as a limiting error and within 5 per cent as a rule, and until able to set off these estimated distances by estimation on the sketch with the same degree of accuracy.

The student should learn to check constantly on the shapes of his map contours by mental comparison with the direction and estimated distance to points on the contour on the ground. Such comparison will serve as an effective guard against any serious errors in representation. Drawing contours as a result of deliberate and practiced estimate is a very different thing from merely drawing lines by guess and calling them contours.

Speed in Sketching.

In military sketching, speed is a very desirable quality, but it should be cultivated only after a satisfactory habit of accuracy has been acquired.

Speed in sketching results principally from making every move count, and from moving all the time. The methods of setting up and orienting the sketching board should be noted carefully, for they are the methods involving the minimum of lost motion.

The next item in time saving in sketching is the ability to decide quickly upon the exact work to be done at each station, and a definite plan of work. Make all the necessary pointings with the alidade, and when these are finished read all the vertical angles with the clinometer.

The third item in speed is the substitution of rational and practiced estimate for actual measurement in the location of points upon which nothing else depends. Estimate must never enter along the main traverse.

There is one time-consuming item against which we may as well be on our guard from the start, and that is the unnecessarily short shot on the traverse. The general rule is to get as far along at each shot as possible, generally as far along as you can see. Every unnecessary set-up of the sketching board means a loss of several minutes.

The beginner is apt to assume that, if his traverse lies along a road, his line of sight must lie within the road itself and hence sights on the first bend. The sight should go as far along the road

as is reasonably possible. In sighting to a bend where the road disappears from view, always sight on the inner side of the bend so that the sight may be prolonged as far as possible.

Having sighted forward at a point such that a bend intervenes, it is necessary to pace the distance around the bend of the road itself, whereas the distance desired for plotting is that along the chord of the curve. It will be sufficiently accurate in practice to estimate in strides the maximum offset from the chord at the bend, and deduct one-fourth of this number from the distance in strides around the curve.

Mounted Sketching.

Mounted sketching is usually understood to mean road sketching. In any case, the use of the horse confines the measurements of distances to roads.

In one sense the term "mounted sketching" is a misnomer in that only the measurement of distances is done mounted. The sketch itself is drawn while dismounted, for obvious reasons.

It is usual to assume that the sketcher has a mounted assistant, who takes and records the time between stations and holds both horses while the sketching is being done at the halts. It is perhaps better for the sketcher himself to take the time records, because he knows what data he wants. If he has no assistant, he must himself hold the horse at the stations. This is done preferably by standing on the reins. If the reins are held on the arm, a toss of the horse's head is annoying.

The methods of mounted sketching differ very considerably from those used in dismounted sketching. The prime object is to get a traverse of the road, with such incidental information concerning the topography along the road as it is possible to procure.

The traverse itself is made by making forward shots on selected points, reading the vertical angles, and plotting the distances between traverse stations from the time scale of the horse.

The data for plotting houses, bridges, stream courses, crests of ridges, boundaries of woods, etc., is recorded on the time pad, which is conveniently ruled so that the time at which an object is passed and its distance from the road can both be indicated by a mark. Each page of the sketching pad is arranged to hold the memorandum record of five minutes on the time scale.

The distance between stations is covered at a trot, and the stations must be an average of $\frac{1}{2}$ to $\frac{1}{4}$ mile apart if proper progress is to be made. The stations are selected on the crests of ridges if practicable, so that the sketcher may look back over the ground to assist in drawing its representation. Otherwise the notes and the memory must be relied upon.

Although a fairly satisfactory traverse can be run by mounted sketching, it is needless to remark that the representation of ground forms and elevations from such data and impressions as can be gathered while passing along the road at a trot, is only a very crude approximation.

The usual mounted road sketch is executed on a scale of 3 inches = 1 mile, (R.F. $\frac{1}{21,120}$), V.I. 20 feet. The contours are supposed to show a strip of country 400 yards wide on each side of the road. At important positions, the contours may be extended further and they must of course be omitted where the ground is not visible from the road.

The utility of contours drawn within the limits prescribed and by the means available in road sketching is very doubtful. However, the indications from the road sketches of adjacent roads may give a clue to the trend of the intervening ground.

Trench Sketches.

It will be frequently necessary to make sketches showing the lay-out of trenches, dug-outs, and the many auxiliary constructions. In such sketches, only a plan will be required as a rule, and the necessary view to show the contours may not be possible.

The difficulties in running the traverse for such a sketch will lie in the short shots and the presence of a great deal of metal.

The short shots require the adoption of a very large scale, and the presence of metal requires orientation of the sketching board by back sights instead of by the needle.

Orientation by back sight is accomplished by placing the alidade on the line drawn for the forward shot and then turning the sketching board until the alidade points back along this line on the ground. The sketching board is then parallel to its previous orientation.

Lettering on Sketches.

The topographical draftsman must be able to execute the several different Roman and Gothic alphabets required by convention for lettering different classes of information on finished topographical maps.

The topographer requires no more than the ability to letter names and number contours neatly and plainly. The best form of lettering for his use is that in which a satisfactory degree of proficiency can be acquired with a minimum of practice.

The alphabet which meets this condition best is the single-stroke Gothic generally known as the Reinhardt alphabet, in honor of Mr. C. W. Reinhardt, who first systematized its construction.

Alphabets. The Gothic italic alphabet, formally executed and giving the direction and order of strokes, is shown in Fig. 40. This alphabet should be studied carefully as to form of letters and general style. The order and direction of strokes in the vertical Gothic alphabet are the same as in the italic. Both of these alphabets should be learned.

It is best to aim at reasonable speed in lettering combined with fair quality rather than to fall into the habit of labored lettering in the attempt to secure the best possible quality. Fig. 41 is an example of the former kind of lettering. The plate for this figure was made in twenty-eight minutes. The vertical Gothic letter-

ing was executed in pencil and then in ink; the italic Gothic directly in ink. The plate is reproduced without reduction.

Fig. 40.—Gothic Italic Alphabet.

The letters of the Italic Gothic alphabet have a slope of 2 to 5, i.e., two units measured horizontally and five vertically downward

from a point serve to establish the slope line. The height of the bodies of the small letters is two-thirds that of the capitals.

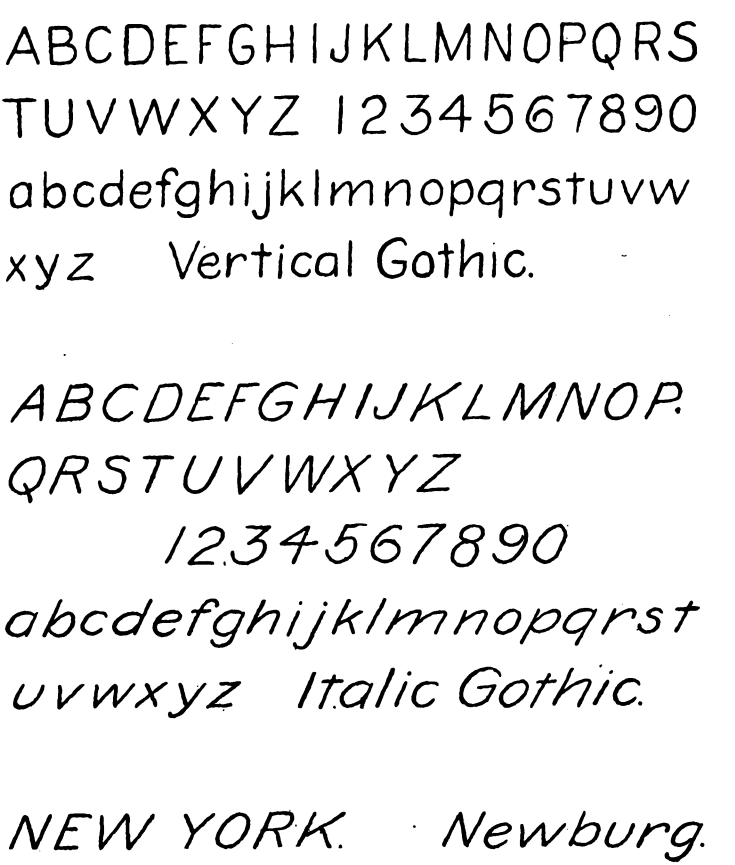


Fig. 41.—Vertical and Italic Gothic Alphabets.

The basis of all letters is the straight line and an ellipse. These are vertical in the vertical alphabet. The straight lines

have the 2 to 5 slope in the italic Gothic and the major axis of the ellipse has a slope of 45°.

Hints for Practice. Lettering is done with a finger motion. A firm and comfortable position of the hand is necessary. The pen or pencil should be held in about the same position as for ordinary writing, care being taken not to cramp the hand by squeezing the pen or pencil.

For purposes of practice, the letters should be divided into groups.

(1) Those formed entirely of straight lines:

l, t, i, k, v, w, x, z.

(2) Those involving the ellipse:

o, a, c, e, s, d, g, p, q, b.

(3) Those formed by a combination of straight and curved strokes:

r, h, m, n, f, j, y, u.

These groups should be practiced in order as given. The form of each letter should be learned from Figs. 40 and 41. Careless practice in lettering is time worse than wasted. Nothing is gained by repeating line after line of letters carelessly or wrongly formed.

Speed should be increased gradually as proficiency is attained in forming the letters. The strokes that make up a letter should be executed in a regular cadence. The cadence should be gradually increased. After the form of the letters has been firmly fixed in the mind and reasonable proficiency and speed in execution gained, practice should be undertaken in grouping letters into words, and then words into sentences.

As a general rule, the space between letters should be approximately one-quarter the height of the letter, and the space between

words about one and a half times the width of the letter *n*. The space between sentences is greater. It is best to learn to rely upon the eye to govern the spacing. All rules for spacing are subject to exceptions, and in many cases the spacing must be modified to conform to the margin. What is desired in the end is lettering so spaced that the eye is not offended by any unduly wide or narrow space at any point.

Lettering in pencil is best accomplished with a 6H pencil sharpened to a very fine conical point and used with a very light touch. The test of all pencil lettering is that it must be possible to erase it cleanly and quickly with a soft rubber eraser.

In lettering in ink, the weight of the stroke should increase with the height of the letter. This requires the use of a pen point suited to the work in hand. Gillott's 659 (crow-quill) or 170 may be used for fine line work, and Gillott's 303 or 404 for medium weight lines. Hunt's Bowl-Pointed 512 or Leonardt's Ball-Pointed 506F give a weight of line suitable for lettering about $\frac{1}{4}$ inch in height.

Aptitude is a valuable asset in learning to letter, but proficiency is within the reach of all who will study the forms of the letters carefully and then devote a reasonable time to careful and systematic practice.

CHAPTER XIV

PANORAMIC SKETCHING

Purpose. In the identification and assignment of targets for both field artillery and machine-gun fire, it is desirable to record the positions of the targets in some form such that they may be identified easily and unmistakably. For artillery observation points, it is desirable to be able to identify points of special enemy activity and identify them so that a record can be made for the use of successive reliefs.

All of these purposes are best fulfilled by a panoramic sketch, which is nothing but a conventionalized perspective landscape sketch, with certain data entered upon it with reference to the azimuth and range to targets from the point where the sketch was made.

Perspective.

In order to make a panoramic sketch, some knowledge of the laws of perspective is necessary, particularly in regard to the vanishing points of parallel lines. From the standpoint of the use of the sketch, it will serve its purpose if the points in the landscape can be identified, even though the perspective be comparatively crude. Many of these sketches, in practice, are nothing more than approximate horizon outlines with a few of the intervening sub-crests.

Crest Lines.

The first step in the drawing of a panoramic sketch is to draw the approximate representation of the crest lines. The landscape must be studied carefully in order to pick out the lines of

the sub-crests and the hill over-laps, because upon the rendering of these few lines depends much of the effect of the sketch. These crest lines should be drawn in the lightest possible line so that corrections can be made easily, until the entire outline is satisfactory. The aids to the correct drawing of the crest lines will be described in connection with the sketching pad.

Distance Effect.

The sketch should, in so far as the skill of the sketcher permits, give a correct impression of the landscape and, therefore, should give the impression of increasing distance as the objects represented are farther from the point where the sketch is made. This is accomplished by making the outline of the distant horizon in a faint, sketchy and discontinuous line. The lines of the sub-crests are then touched up in a gradation of lines, depending upon the distance, so that the nearest objects shown in the sketch are in bold, black strokes. Cleared hills are shown in smooth outline, wooded crests by an irregular outline made up of small loops like the tree symbol in Fig. 10.

Full advantage is taken of the effect of the convergence of parallel lines in perspective to strengthen the effect of distance.

Conventions.

The representation of the various features of the landscape is more or less conventionalized. The representation of roads, buildings, trees, clumps of woods, etc., is shown in Figs. 44 to 46, inclusive, at the end of this chapter.

Sketching Pad.

Two forms of sketching pad are provided in our service, one for the use of infantry, the other for the use of the artillery. They do not differ materially except that the artillery pad has additional ruled spaces at the top of each sheet for the artillery firing data. The School of Musketry sketching pad is shown in reduced size in Fig. 42. The sheets of the pad are $8\frac{1}{2}$ by $5\frac{1}{2}$ inches. Verti-

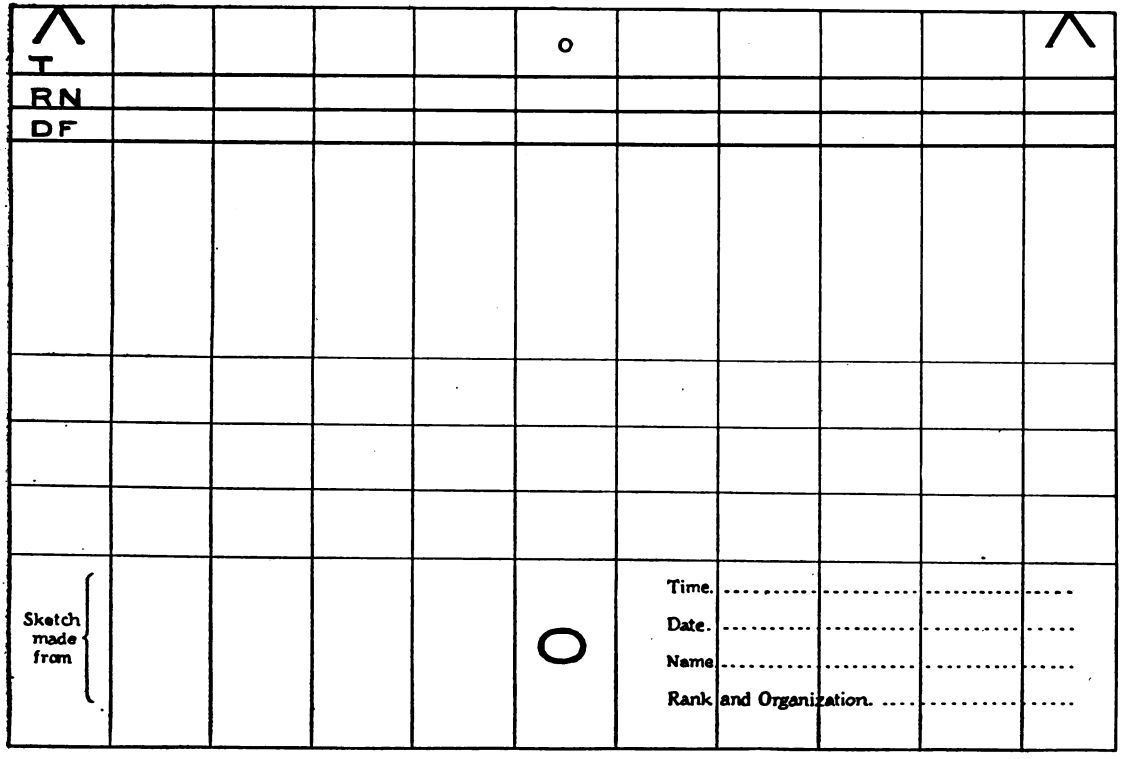


Fig. 42.—School of Musketry Sketching Pad.

cal lines in light blue are ruled on the paper. These vertical lines are used in dropping lines from the landscape to their positions on the sketch. The $\frac{3}{4}$-inch spaces between these vertical lines subtend an angle of 50 mils (1 mil = $\frac{1}{6.400}$ of a circle) when the pad is held at 15 inches from the eye. To insure this distance, a cord is secured to the pad and knotted at exactly 15 inches. The knot is held between the teeth in measuring the deflection of objects in the landscape.

Four horizontal lines are ruled at intervals of $\frac{1}{2}$ inch just below the center of the sheet to mark the vertical limits of the sketch. At the top of the sheet are two orientation marks, and horizontal lines giving spaces for the description of the target (T), the range (RN), and the deflection (DF) in mils from the reference point.

Practice in Panoramic Sketching.

The beginner will be confused by the mass of detail in the landscape before him. All but the bare outlines of the features must be ignored. Prominent objects in the foreground are omitted entirely, because they are of no importance in the use of the sketch.

It is best before attempting to make sketches from the landscape to practice copying typical sketches, in order to become accustomed to the representation of objects in the distance, and to the extremely small size of the objects that are drawn in the sketch. The next step is the drawing of imaginary landscapes, after which sketching from a landscape should be attempted.

Making the Sketch.

The sketching pad is held in front of the eye, the upper edge of the paper horizontal, the cord knot in the teeth. The pad is shifted until the desired sector is included between the orientation marks. The points in the sky-line now appear at the edge of the pad vertically over the points where they are to be drawn. These points are marked at the edge of the pad. The pad is now

lowered, and the highest point on the sky-line is indicated in its proper position on the highest of the horizontal lines of the sketching area in the center of the pad. Other points of the sky-line are now drawn in their proper vertical and horizontal positions. The sky-line is drawn in lightly. Other points, crests, targets, etc., are then entered in the same manner, again holding the pad up before the eye if necessary.

By this method the objects will be drawn in their proper lateral positions. The vertical proportions should be so determined that the sketch will lie between the limiting lines. This may be done by holding the pad up, and lowering it by four equal stages, so as to show what ground features belong on each of the horizontal lines of the sketching pad.

In making a sketch, no effort should be made to obtain artistic effect, and it is necessary to avoid too much detail or the sketch will become confused. Outlines only are shown.

A prominent object is selected as a *reference point.* This must be an object easily recognized by anyone using the sketch. A vertical line is drawn to this point and a heavy arrow-head placed on the line near the object. The line is labeled 0 in the deflection space. The name or description of any target is indicated in the target space, the range in the range space, and the deflection in mils from the reference point to points indicated by vertical lines drawn from the objects up through the deflection space. When the range is measured by a range finder, the range entered is underscored; when estimated, not.

Panoramic sketches must be done in the shortest possible time. Ten minutes is the usual time allowed for completion.

When a sketch is completed, the pad is held in the position in which the sketch was made, then turned downward into a horizontal position, the compass north determined by placing the compass on the pad, and a north line is drawn at the circle at the lower edge of the pad.

An example of the completed sketch is shown in Fig. 43.

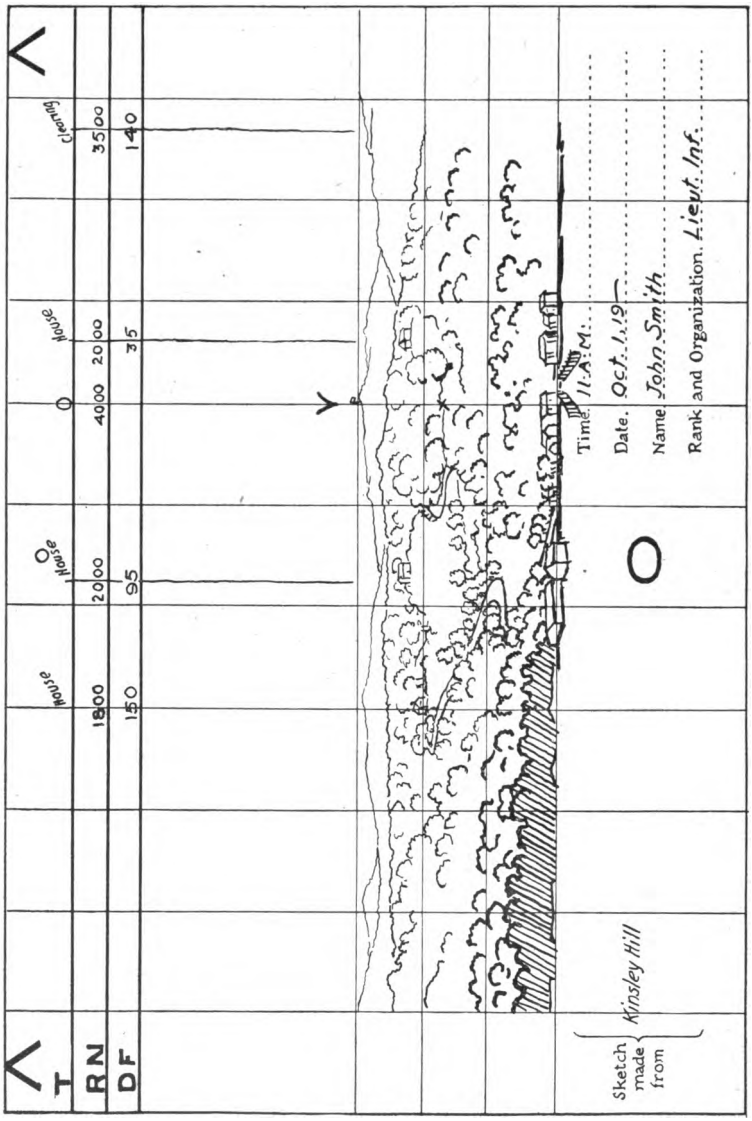


Fig. 43.—Panoramic Sketch.

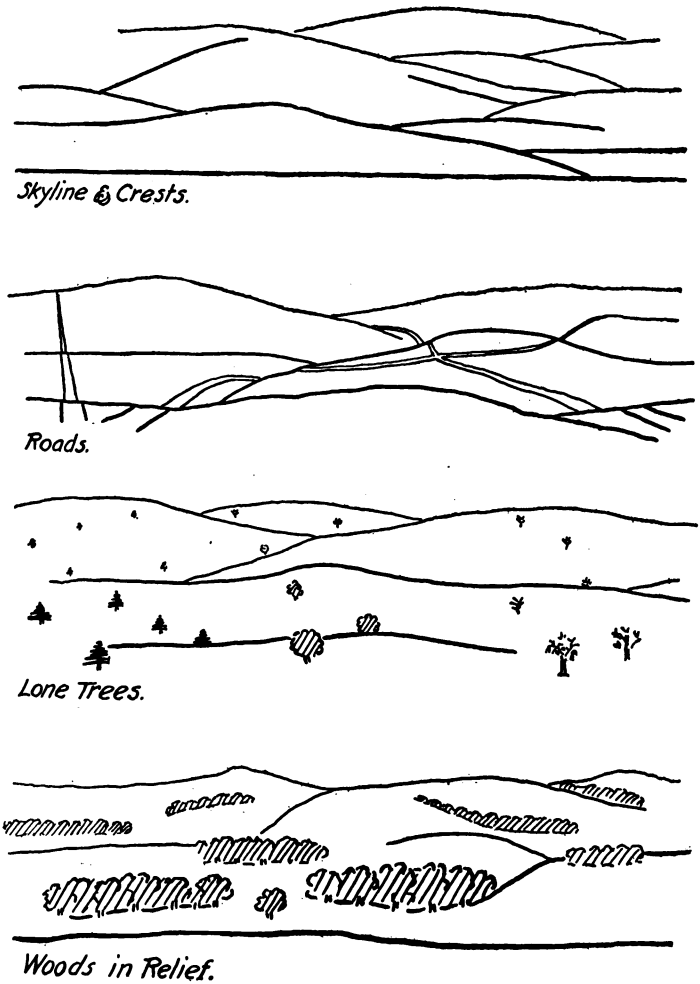


Fig. 44.—Panoramic Sketching—Conventions.

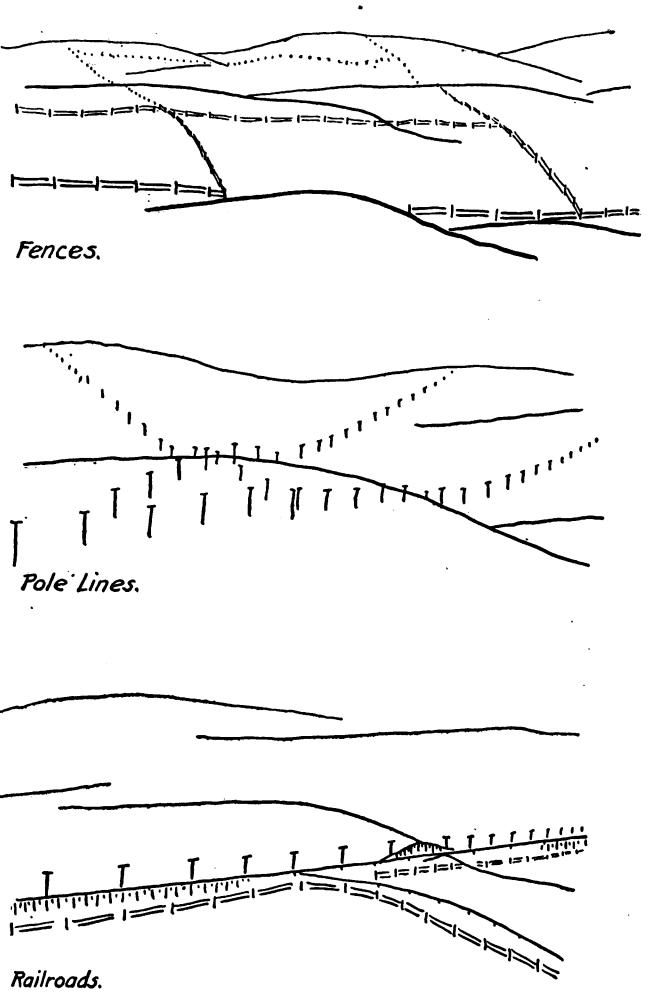
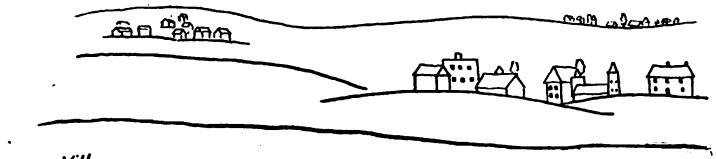
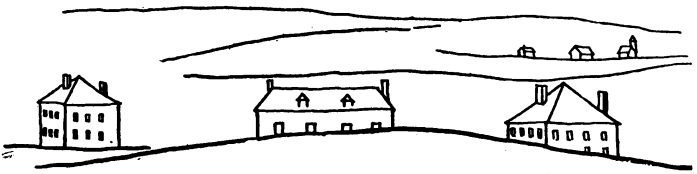


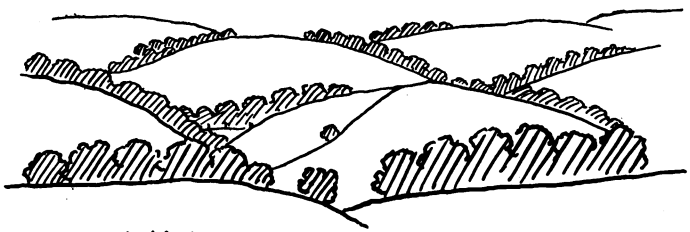
Fig. 45.—Panoramic Sketching—Conventions



Villages.



Buildings.



Woods behind Crests.

Fig. 46.—Panoramic Sketching—Conventions.